TRANSACTIONS

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

MEETING OF NOVEMBER 18-20, 1918

CLEVELAND

#7

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SOCIETY OF MOTION PICTURE ENGINEERS

Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

An Active Member is one who is actually engaged in designing, developing or manufacturing materials, mechanisms or processes used in this or allied arts, or who is interested directly in the art.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance fee for all members shall be twenty-five dollars ($25.00). The annual dues shall be ten dollars ($10.00), payable in advance before the annual meeting (October) of each year. That is, the total fee for the first year, which includes the entrance fees and first annual dues, is $35.00 for all member.

PRESIDENT'S ADDRESS

Cleveland, October 21, 1918.

Gentlemen:

This meeting of the Society of Motion Picture Engineers is an anniversary of two successful years, and begins a third which holds a promise of still greater usefulness and solidity.

We have preserved our identity and individuality on the sound theory that we are strong enough to go it alone, and have steered our little craft so far in safety, and to a position of credit and respect in the industry.

Unselfish service has been our watchword from the first, and if this source of inherent power is guarded with unceasing jealousy, I believe we may confidently look forward to a stable future of still greater usefulness, and an enlargement of our Society into an international organization. Such an attainment is perfectly feasible, for the basis of our industry, the picture ribbon, is standard the world over.

The papers read before this Society represent an accumulation of specialized knowledge, prepared by men expert on the particular subject of the discourse, and with selfish interest left out. And printing these papers puts them into convenient form to be consulted and studied at leisure, and they are already much in demand.

The preparation of these papers, the unselfish contribution of busy men of affairs and always at a personal sacrifice, is particularly a notable labor of love in these strenuous war times, and it seems therefore particularly opportune at this time that I should express the appreciation of the Society for their contribution of these valuable papers.

I think all the Transactions should be collated and bound into a single volume, for these papers are invaluable. The information contained therein can be found in no other book anywhere. Not only will our own members want these bound copies, but I believe others will also, and provision for making them readily available should be arranged.

As we go on, this wealth of specialized information will be augmented and be more and more attractive to those who seek answers to their motion picture problems. And there are many subjects which have not yet received our attention because of lack of time or opportunity for full consideration of the subjects. For example, a standard unit screen surface by which we can compare picture screen surfaces. That proposed at one of our meetings, namely, oxide of magnesia, was laid over for action later. I think we might profitably take it up at this meeting.

A troublesome subject badly needing standardization is film tinting for the different colors. The present haphazard practice leaves the lighting engineer and the machine designer nothing but a compromise course, and the projectionist can do but little more than ignore the subject entirely.

Red should not cut off 79% of the light, orange 62% and blue 40% as is now very, very frequently the case. Tinting for color does not need to be dense, but as long as some studios tint heavy and some light

for the same color, the engineer cannot make the best machine attainable. Standardization of tint will change all this favorably.

Another very fruitful source of investigation is the excessive loss of light in the optical system of our projectors. In no other lighting system are such losses to be found. In searchlight work 60 to 90% efficiency is common, while in motion picture projectors, efficiencies of less than 5% are the rule. I think you will agree with me that this is a promising field of research. The beam of light in our picture machines is only a parallel searchlight beam somewhat more concentrated, and intercepted by a stencil which causes shadows, half-tones and high lights on the screen to produce a picture in monochrome.

Perhaps no other single object has more warrant for intensive study by our Society than this one of light conservation for it has many and rather wide reaching effects. Not only will it have a bearing on education by making this universal printing press available in more remote places than is possible now, but it will materially reduce the fire risk by reduction in the heat attendant on the production of light.

In the arc lamp the light falls off directly as the current, while the heat as the square. Therefore, if the current and therefore the light can be reduced by four the heat will be decreased by sixteen, certainly an object worthy of the attention of any of our engineers.

These are but suggestions, for there are many subjects needing our attention. The laboratory of the producers has not yet given us the membership greatly to be desired in our discussion of problems involving the art where production touches elbows with reproduction.

When all these things have received deserved attention, our work throughout the world will be more and more felt, for it is not with cold reasons that we may judge of the possibilities of our industry when standardized.

The motion picture is a new teacher speaking to every man in his own tongue, including those who cannot read printed characters at all. It is also a new art expression. For centuries we have had the art of form, architecture, sculpture, drawing; the art of sound, music and singing; now we have the art of motion, and its limitless possibilities as an instrument of expression are but just beginning to attract the artist. The industry has brought forth a new type of artist. Let us quickly get a standardized medium for this new artist.

SOCIETY HISTORY

Our Society has now definitely reached the growth where its influence is sought. This enviable state is gratifying to me, personally, as you will see if you will permit me to recount the history of its birth.

Every national organization of the motion picture industry, by whatever name, has had its Committee on Standards. I was first elected to membership on that Committee of the Motion Picture Board of Trade. We met once, then "blewey." I was next elected on a similar Committee of the present National body, and on call made a trip from Washington to New York to find not a single other member or officer present, with the exception of the secretary of this Com-

mittee who was also Secretary of the National Association, in whose office we were supposed to meet. At my insistence he phoned members nearby, but without result. "Blewey" again.

On the way home that afternoon I fidgeted in my chair, fussed over conditions which made for such fruitless efforts, and determined I would put my personal standing in the industry to the risky test of inviting engineers to come to Washington for the purpose of organizing a Society of Motion Picture Engineers, on my own responsibility. I am terrified even now every time I think of the chagrin I would have felt had the call gone unacknowledged.

But a most gratifying response rewarded my anxious wait on the fateful day, for Mr. Don J. Bell came down from Chicago, Messrs. Willett and Westcott from Boston; Cromelin, Cannock, Gillett and Miles from New York. These gentlemen with Mr. Brockett and myself formed a very substantial nucleus indeed. We adopted a constitution and by-laws, and adjourned to meet in New York in October after incorporation should be completed.

And right here was where our little bark first struck rough water. Twenty-four hours before this New York meeting our Secretary sent out unauthorized notices that the meeting was adjourned three months to meet in Atlantic City. Happily this calamity was averted when a considerable number of telegrams, hastily dispatched, collected a very substantial gathering, and permanent officers and directors were elected. This was indeed a critical time. I remember that a gentleman met me in the lobby when the future of the Society was trembling in the balance, and introducing himself, said he came from Pittsburgh with another gentleman both of whom would like to join the Society if it was going to amount to anything. I told him it was going to amount to a-plenty even if I had to knock down and drag out all obstructionists. These two gentlemen, Mr. Wible and Mr. Campe, have proved stalwart workers, and have added materially indeed to the stability of our organization, as you all know.

Our next meeting, Atlantic City, marked the beginning of our real purpose—namely, the dissemination of specialized data relating to our art; and the next meeting held in Chicago, added a set of unanimously-adopted standards. This data and these standards have already been in considerable and growing demand. Each copy of our Transactions is valuable, but I think all of us will agree that our last printed volume is not only a very valuable publication but one of the finest pieces of printed matter ever publicly distributed.

Our Society is now a well-knit body, and certainly the time has come when much of the arduous work which necessarily during the heading months of such a body devolved upon the office of the President, can to advantage be delegated, as is demonstrated by the excellent work of the Papers Committee.

If you will permit me to speak from this experience as your Presiding Officer I should like to make a few recommendations, two at least, that I think worthy to be adopted at once. First, that the officers who pass on expense vouchers and sign checks therefor, whether the treasurer and president, or a vice-president, should, for convenience and efficiency, reside in the same city. Second, that to the duties of the

Papers Committee be added responsibility of the publication of the Transactions, certainly so after the work now in hand is completed and out of the way.

As I said at the Rochester meeting, I am not a candidate for a third Presidential term. But before relinquishing my opportunity to speak from the chair, I should like to confess to two errors of personal judgment. The first was the effort to prepare at the request of the Federal Government, a camera specification for war work, in conjunction with Don Bell and Carl Gregory. It wasn't wholly a success because these camera authorities couldn't agree. This should have been a warning to me that the request of the Underwriters Laboratories that we adopt an alleged ideal specification for a projecting machine was unlikely of approval by makers of diverse models, which was my second mistake.

It did one thing, however, well worth while. It clarified the atmosphere and made more distinct to me and perhaps to others of us, the objects for which this Society was organized and even more strikingly the things for which it is *not* organized.

For example, the Society of Motion Picture Engineers is not a judicial body to settle controversies between conflicting interests or to promulgate recommendations which make for class-discrimination. If our Society ever degenerates into a contest between factions each trying to use the Society for personal advantage, then our usefulness is ended and our organization will soon break up as others in the motion picture industry have already done.

What we *did* organize for was to set our official seal on standards generally recognized as standards; and second, and perhaps best of all, to put into permanent form for world-wide distribution, the specialized knowledge which our members, experts in their particular line, are so unselfishly furnishing for this purpose. And while the official stamping of generally acknowledged standards is a necessary duty, for myself I have found the most interest in our meetings has come from the valuable papers read and printed, and I don't believe the limited time of our meetings can be spent in a more worth-while manner.

And it is by the printed copies of these papers that we shall be remembered, for they will doubtless find their way not only into the hands of our members and others of our own industry but into libraries generally. Perhaps nothing is more to be desired or would add more to our prestige or usefulness.

And there is a wonderful collection of data already collated. Do you want to know the percentage of loss of light by reason of the tinting of films—it is in the Transactions. Do you want to know the distortion error due to angular projection—it is in the book! Do you want to know the source of loss of light at various points in the optical system—it is in your own printed copy. Do you want to know the cause of the stroboscopic effect of shutters—it is in the booklet sent our members. Do you want to know the proper current density for carbon arcs—reach for the bound volume. Do you want to know the advantages and disadvantages of various electric current devices—it is in the unselfish report of that Committee.

Gentlemen, I thank you for hearing me through, I have a fatherly feeling for this Society.

C. Francis Jenkins.

STANDARDIZATION OF THE MOTION PICTURE INDUSTRY, AND THE IDEAL STUDIO

By JOHN W. ALLISON

Owing to the tremendous growth of the industry from the beginning, due not only to its novelty, but primarily to its human interest, the Pioneer Producers had their hands full in trying to supply the demand for motion pictures which was increasing by leaps and bounds from day to day, so that it was impossible to stop and give thought to the systematizing or standardization of production. The public found a new source of entertainment, and the public would not be denied. It *would* have its fill, and while the *novelty* of this *eighth power of the world* was upon them, they gave no thought to the *quality*. What they wanted was *motion pictures galore*, and the wise producers gave them what they wanted, and waxed rich thereon. They had found big profits on small investments, so they thought: Why not let well enough alone?

When the big financial interests of the country saw the *bank accounts* of these pioneer producers climbing up into the *hundreds of thousands*, they thought they were *missing something good*, so they got into the game, and today the *motion picture industry* stands among the foremost industries of the nation, and those engaged in the industry are higher paid per capita than in most any industry in the world, notwithstanding which, most producers are able to make handsome profits on the money invested. And this on top of the fact that there is probably more money wasted through lack of proper standardization in the industry, than any business in the world.

Now I am not going to talk on the *art* or *stage-craft* side of the industry at all. I know nothing about it. The industry at large is in the hands of the most successful dramatic producers of the day, men who have catered to the amusement of the public for years. They have gathered around them the most popular artists for their casts, and the most able directors to stage their stories, together with the necessary help. All of which they *know how to select*, for they have been employing people in these lines for years. The motion picture industry, however, calls for a new class of help with which many are not so familiar, I refer to the *photographic department*, on whose efficiency *really depends the final result*, for if *they* don't make good, the answer is *failure*. So, it is on the *standardization* of the *photographic department* that I am going to speak, and as the results depend solely on *proper exposure*, this will be my chief topic. Right here I want to say that no system of standardization can be carried out without thoroughly competent and well paid help.

Standardization of an industry should begin at the beginning, and as the producers of motion picture film have a standardized product to start with, *i. e.*, the film, the first thing for the producer to standardize is the exposure, and this can only be done by standardizing the conditions under which the film is exposed. Of course, I refer to work in the studio.

Messrs. Hurter & Driffield, of England, whose research work in the photographic field is recognized throughout the world, put great stress on the necessity of securing a technically perfect negative. Let us quote a few words from their little book on "Photo-Chemical Investigations and Methods of Speed Determination:"

> While we quite realize that the artist will always produce the best *picture*, we contend that the scientist will produce the best *negative*. The photographer, therefore, who combines scientific method with artistic skill is in the best possible position to produce good work.
>
> The truthful representation of light and shade involves the production of a technically perfect negative, *i. e.*, one in which the capacities of its graduations are proportional to the light reflected by those parts of the original object which they represent. Our investigations show that such a relationship does exist, but only when a plate has received what we term a *correct exposure*.
>
> While many photographers attach very little importance to accuracy in exposure, and maintain that errors may be readily corrected by suitable modifications in the composition of the developer, we have always strongly insisted that a correct exposure is an essential foundation if we aim to procure a technically perfect negative. It must be clearly understood, however, that, by a correct exposure we do not imply that there is necessarily one exposure, and one only, which will yield a negative answering to our definition. Fortunately most plates admit of some latitude in this respect.
>
> Our contention is that the latent image, false in its gradations, cannot, by modifications in the constitutions of the developer, be made to yield a visible image true in its gradations. The practice of photography, by methods of scientific predetermination, imperatively demands a correct exposure as a fundamental condition."

The standardization of the exposure so that at all times every foot of film exposed in the studio will be uniform in density will do away with the necessity of variations of timing on the printer, and eliminate the uncertainty of the finished result, also one can predetermine the screen results when toning or dying is resorted to.

I have been working on an indirect system of studio lighting to standardize the exposure, in which the volume of indirect light is governed by the cubical area to be lighted, and in addition to which the light effects are secured by the use of a few diffused direct light units. In this way the photographer can exercise his artistic ability with the assurance of a perfectly exposed negative resulting. Of course, studio conditions will have to be somewhat changed from the present methods of working, but the certainty of the results will warrant the expense.

Ninety percent of the time we spend in indirect or reflected light. Such being the case, why should we not make our photographs in the conditions under which we normally live. The Eskimo is a specimen of a human being who spends most of his life under direct light. Now, who would want to be photographed to look like an Eskimo?

To my mind the use of undiffused direct light in the studio is a great mistake. Besides causing terrific eye strain for those working under it, it is responsible for the chalk and lamp black effects so often seen upon

the screen, which is the result of overexposing the high lights and underexposing the shadows. No laboratory man, however efficient, can make a good negative from a film exposed under these conditions.

Under present working conditions, with every camera man turning in film made under differing conditions of lighting and exposure, it is really remarkable that the laboratories get as good results as they do. Therefore, can you imagine what it would mean if the conditions were such that the director and camera man absolutely *knew* that the exposure would be correct, and the laboratory man *knew* that the film will require exactly so many minutes in the *standard developer*, at a *standard degree of temperature*, to produce a technically perfect negative?

The question will arise, does this method of standardizing exposure rob the camera man of any of his honors and glory? The answer is—No, for it makes him absolutely sure of his results, and permits him to use his ingenuity to the limit, even to securing the most delicate of lighting effects.

The use of combined daylight and artificial light is bad practice, as the actinic value of daylight is changing every hour of the day and month of the year. The immense glass studios at present in use are unbearably hot in summer and excessively costly to heat in winter. A cloud passing over the sun during a daylight exposure in the studio is only one of the disadvantages of working under glass. A scene partially made in one day and having to be matched up on another day (or even from morning to afternoon) is almost an impossibility. Of artificial light used in conjunction with daylight, at least 50% of the light is lost through the inability to confine the light to the area required. Light is like sound. It goes on forever, and unless confined where wanted it diffuses with the daylight and its value is lost.

The ideal studio, to my mind, would be one made up of separate rooms for settings, the partitions of which could be removed as required, with all the light equipment handled from above, both indirect and diffused direct. The amount of saving in floor space over present day method being no small item of convenience and saving, because we are paying for space by the square foot. With these separate rooms for the settings, each director, his staff and company are working on a picture entirely isolated from those working on other sets, they would be free from noises and distracting conditions, to which they are subjected under present methods. The lights for each set being controlled by switches in the settings where the director could turn them on or off as needed, would be a great saving of time often lost while waiting for the assistant electrician to do this for him, and during rehearsals only as much light as is really needed would be thrown on the setting.

So much for the standardization of the exposure.

The real need of the industry is *team work*, not grand stand *play*. No one man can know it all nor take the credit for all. The book of the motion picture has three chapters: Literature, Art and Science. Let each one to his own. When the camera starts working and making the record, all that literature and art could do has been done, and unless the exposure is right, neither literature, art nor the science of chemistry can make possible an acceptable result on the screen. And strange

as it may seem, the failure of many fine stories, acted by fine casts, is due to poor photography, for which there is no adequate excuse, as photography is an exact science, the results of which can be predetermined with as much certainty as the weaving of cloth. Exterior exposure can be determined by the use of light measuring instruments, so that they will require the same treatment in the laboratory as pertains to those made in the studio.

The standardization must also embrace the use of *rational color-combinations* for the settings. Many color-combinations beautiful to the eye are wholly unfit for photography, because the film will not record them as the eye sees them. This is a subject requiring the greatest study, particularly in studios where both the arc-lights and mercury vapor lights are used, as the spectral quality of the two lights is entirely different. The film is capable of recording a certain part of the spectrum, and what it registers depends upon the source of light. The nearer you get to daylight with your artificial lights, the better the results you get on the film, and by reason of the limited region of the spectrum to which ordinary negative film is sensitive, the fewer colors used in the studio, the better. Reds, dark browns, greens and yellows, should not be used, except where very heavy backgrounds are wanted for visions, etc., as these colors have no effect on the film. Blank-white should be avoided, as it tends to chalkiness, and hard results. Combinations of light-reflecting colors,to which the film is sensitive in some degree should be used to secure harmonious results, and all combinations that give extreme contrasts on the film should be avoided, as they jar the senses, and detract from the full enjoyment of the story.

Trick-photography must be used sparingly, it is apt to detract from the story, and is no longer a novelty. The smoother the presentation of the story, the more enjoyable it will be.

In the making of *close-ups*, great care should be taken not to get them on too large a scale. There is nothing so ludicrous as a head about four times the natural size.

Regarding the Laboratory

The laboratory must be in charge of an *expert photographic chemist* of wide experience, not merely a good darkroom man, for should any trouble develop in the processes, you want a man who can put his finger on the cause *immediately*.

One of the chief requisites of the laboratory is a *research department*, where all film should be tested out immediately upon its receipt from the factory, and a record kept of all tests. In order to do this under proper conditions, a small studio must be built embodying the identical conditions as prevail in the main studios, as to amount of light per cubical area, etc. Here all tests should be made for studio practice, such as speed of film, color-combinations for settings, tests of new subjects for the casts, etc.

The research department should make all tests of new chemicals and processes and lay out the after treatment of the positive film, such as toning and dying. It should also test the solutions of the laboratory workrooms daily, and keep them up to specified requirements.

The research laboratory should be thoroughly equipped with the proper instruments to make these tests, and a complete photographic library installed as far as modern practice is concerned. Here also should be received and kept on file all pamphlets issued by the different manufacturers, particularly the pamphlets issued from time to time by the *Research Department of the Eastman Kodak Co.*, which are the most valuable contributions to photographic literature published in this country. Here also should be found the *British Journal of Photography*, and their *Annual Almanac*, and any other technical papers of interest to the trade.

We will assume that the laboratory workrooms are equipped with the most modern and improved fixtures to carry on the work, so we will proceed to outline what we know should be done.

The first thing your laboratory chief should do is to have a chemical analysis made of the water supply. This analysis should be submitted to the manufacturers of the film, to find out if it is suitable for obtaining the best results with the formulae supplied for the film. If the film makers find that an adjustment of the formulae is necessary, they will so advise, and their advice should be followed to the letter. *They know what treatment their* film requires, and it stands to reason that they are not going to recommend any developer for their film, but the one they know is best. With this specified developer, they will give a *standard of time and temperature* for the development, or what is known as a *factor* for the formulae to get the best results, and if the instructions have been carefully carried out, the results will be uniform at all times. Of course, as the development of the film shows up the developer by the depositing of bromide, which takes place in the conversion of the exposed silver-bromide into the metallic silver, which forms the image, the *factor* will change, and this change should be noted day by day for the work in hand.

As the ingredients of the developing solutions have a tendency to settle, thus making the solutions of varying strength throughout, a system of syphoning, or pumping must be installed which will keep moving the solution from the bottom of the tank to the top. This will keep the strength of the bath uniform.

The developing factor of each bath must be checked up daily, by the development of a piece of standard exposure film. This must be done by the research staff, and a notation of the day's factor attached to the tank. This will govern the time required for development at the existing strength of the bath. As soon as the bath shows the slightest indication of actual exhaustion, it should be discarded at once, the tanks thoroughly cleaned, and a new bath prepared.

The present methods of washing and drying in conditioned air are, to my mind, perfected to a very high degree. This department has been given the proper care and attention, because of the *absolute necessity* for keeping the films perfectly free from dust.

Makeup

As the film records values about like the eye sees them when viewed through a medium blue glass, the dressing-rooms should be lighted with *blue glass bulbs* and the artists put on their makeup under these

light conditions. If the makeup looks right in this blue light, it will be nearly right for the studio, particularly if the studio be equipped with the mercury-vapor tubes. The research department should test out the screen effects of all makeups, for the different types and complexions. This must be done in the miniature studio. The individual makeups should be indicated, and under no circumstances should the artists be allowed to vary from the makeups decided upon for their use. Theatrical artists are so used to the makeup for stage lighting, that it is hard to make them see the necessity for a change when working under the studio lights, but once they get a chance for comparison on the screen, there should be no trouble in getting them to adopt the makeup suitable for the lighting conditions of the studio.

A Few Suggestions

In most of the studio photography, even today, the tendency is either to flat lighting, or to the other extreme of violent contrasts, in the one case making the human face look as flat as a map, and in the other showing chalk-white highlights with absolutely no details in the shadows. Imagine how many photographs the Fifth Avenue Portrait Photographer would sell if he portrayed his subjects in this manner. A careful examination of the show cases of our highest paid portraitists will show the kind of work the critical public demands, and in none of these will you find the class of work referred to above.

The motion pictures still are atrocious in most cases, when they should really be works of art, for what with the care and attention paid to the settings and costuming, every opportunity is afforded to produce masterpieces of the photographic art, and as these pictures are for use as lobby displays to draw the public's attention to the films, no expense should be spared to make them attractive. The same thing applies to the lantern slides, generally of indifferent quality, used for announcements of forthcoming attractions. With so much money spent on elaborate productions, to me it seems bad policy to be penurious in these items.

Some producers have enhanced the attractiveness of their films by the artistry of their titles which are a most welcome improvement over the former stereotyped white-lettered titles, which were not only distracting but very hard on the eyes of the audience. Titles should be modulated in their tones, and be diaphragmed on to the creen, not *shot* on, as this results in shock.

With the foregoing suggestions I must close, summing up as follows:

First: That as the ultimate success of the picture depends primarily upon a perfect exposure, *the conditions under which the exposure is made must be standardized.*

Second: That my reason for insisting upon the necessity of a *time and temperature* system of development, is not only because it is the *only method* by which you can *actually standardize development*, but to do away as far as possible with the *human factor*. The constant changes in the personnel of the developing staff, where the old method of development by examination is in use, makes it almost impossible to get uniform results, and this applies particularly under present labor conditions, when it seems impossible to keep an operating staff

intact, owing to so many being called to the colors, and others leaving to take up positions made unusually remunerative by the needs of war.

Third: That the proper use of makeup, and the use of color combinations must be given more attention in order to get the best results.

Finally: That the above results can only be accomplished by the installation of a research department composed of thoroughly competent help, and then only if their instructions are followed out.

Discussion

In answer to Mr. Burrow's question, as to whether the blue glass bulb referred to was the regular daylight lamp or one of more dense coloring, Mr. Corey said that the blue glass bulb now on the market was referred to, in connection with photography under light that resembled daylight.

Mr. Mayer said the suggestion in Mr. Allison's paper was a combination color filter for viewing the make up and sets as it would appear to the camera—a viewing box equipped with a little optical system for the director.

MOTION PICTURE FILM IN THE MAKING

By GEORGE A. BLAIR

Along with the numerous developments in the past decade and more, in which the motion picture industry has rushed forward so fast and placed itself among the large and leading industries of the country, the Eastman Kodak Company has kept pace in the production of raw motion picture film in the quantities necessary to meet requirements without which the other advances would not have been possible. It is not the purpose of this paper to outline the various steps that have been taken to bring the manufacture of motion picture film to its present state of development, but rather to describe briefly its manufacture and point out the care required to make it uniform in quality.

To manufacture a uniform product in small quantities is one thing, but to make it in large quantities and still obtain a material of unvaried quality is a far more intricate problem. For the latter purpose a wholly different set of apparatus is required, and the development of huge and intricate machines of many different types for large-quantity production has been necessary.

In order to produce film of the highest quality, the greatest care must always be observed and every process carried on in the cleanest surroundings. The importance of cleanliness alone can be understood when it is considered that any fleck of dirt lodged on the surface of the film will be enlarged many times on the screen. After the process of cutting and rolling the film, each strip of stock is carefully inspected to eliminate every piece of film which contains flaws of any kind whatsoever.

In considering the many steps that are required to make motion picture film, it may be well to group the various processes as follows:

(1) The chemical preparation of the raw materials,
(2) Spreading of the support for the emulsion,
(3) Spreading of the sensitive emulsion in a thin layer on the support and
(4) Slitting of large film rolls into stock sizes, inspection and shipment.

We shall now consider these processes in the order named.

Cotton, which is thoroughly cleansed, is utilized in the manufacture of the transparent cellulose base on which the sensitive photographic material is coated. This cotton after being passed through drying machines to remove every vestige of moisture which it contains under ordinary atmospheric conditions, is treated with a mixture of nitric and sulphuric acids to render it soluble.

Special machines, called nitrating centrifugals, are used to mix the cotton with the nitrating acids. These machines consist essentially of large-sized perforated baskets which rotate in vats containing the acid mixture. The cotton is completely immersed in the acid and when the chemical reaction is complete the product, though the same in ap-

pearance, is entirely different in chemical nature, as the original cotton has become pyroxyline or nitro-cellulose.

When the acid treatment reaches the exact stage required, the acid must be expelled instantly and the cotton thrown into water to stop the reaction. The treated cotton is next removed to tanks of water for its first washing, and after being rinsed is passed into centrifugals where water is played on it to remove most of the acid, and then conveyed to other tanks where it is thoroughly washed to remove all traces of acid. The excess water is now removed from the cotton, which is then ready for treatment with the solvents in which it readily dissolves, forming a thick viscous fluid resembling honey, which in factory parlance is called "dope."

The dope is passed through an elaborate system of filters, and finally spread in thin layers on the polished surfaces of enormous wheels, where it quickly hardens and becomes a flexible transparent substance, ready to be formed into a backing for the sensitive coating. It is here especially, that the genius of the factory engineers in solving the problem of large-quantity production has been particularly marked. These wheels form part of immense machines several stories high, weighing approximately 150 tons. The accuracy of these machines is such that the variation from the required thickness of .005 inch is not more than one quarter of a thousandth of an inch.

Silver, which forms part of the sensitive emulsion coated on the transparent base, comes in bars which are placed in porcelain crocks containing dilute nitric acid. Silver nitrate is formed by solution in the acid. The solution of silver nitrate is then poured into evaporating dishes which are placed on steam tables where it is heated to facilitate evaporation to the crystalizing point. After a certain amount of the silver nitrate has been crystalized, the crystals and liquid remaining, which is called "mother liquor," are poured off into draining dishes, which allow the mother liquor to drain. The silver nitrate crystals are re-dissolved and re-crystallized until all impurities are removed. Here again we get that search for purity which exemplifies every operation in the making of high-grade photographic film. The pure white silver nitrate crystals are then placed in porcelain draining baskets where as much of the liquid as possible is drained off. The crystals are next placed in shallow trays and allowed to dry at first on open racks and then in drying closets. They are finally placed in covered jars and stored until needed.

We now come to that mysterious compound, the light-sensitive emulsion on which, when coated on the film base, the invisible or latent image is impressed. By suitable chemical development the image first becomes a negative and is transferred to the positive film and is then ready for projection. From this point all operations in the manufacture of sensitive film are carried on in darkness or dim red light.

To make a sensitive emulsion, a solution of silver nitrate is mixed with potassium bromide dissolved in a solution of gelatine, forming silver bromide which is the compound or emulsion that is sensitive to light.

By carefully controlled methods, only known to the experts and always preserved as trade secrets, this mixture of silver bromide in gela-

tine is converted into the finished light-sensitive product ready for coating on the transparent base. The emulsion for negative and positive film is fundamentally alike, the former, however, being more sensitive and less contrasty than the latter.

The large rolls of sensitized film are then packed in tin cans and stored until ready for inspection and slitting into strips 1⅜ inches wide and from two hundred to four hundred feet in length.

To manufacture a film product of the high average quality now demanded, minute inspection and test at every step in the manufacture from pyroxyline to finished film is essential. This requires chemists in the laboratories, inspectors in the darkrooms and photographic experts who make practical studio and laboratory tests for speed and quality, to which all film is subjected before being finally approved and passed.

Speed determinations are also made by means of the Hurter-Driffield method and are checked by a Chapman Jones plate tester. In the former, strips of film 7 inches long and 2 inches wide are placed in a rotating black sector so perforated as to give with one exposure a series of gradations when exposed for a given time in front of a lamp of known candle power. Each exposure is expressed in candle-meter-seconds. The density or amount of silver for each gradation strip is obtained by means of a photometer and a characteristic Hurter and Driffield, or, as it is commonly known, the H. & D. curve plotted. From the curve thus obtained, the amount of latitude in exposure which is permissible can be readily obtained. The curve commences with a decidedly bent section, and merges into a straight line which finally runs into a curve which is the reverse of the first curved portion. The straight line section indicates the latitude of correct exposure. The H. & D. test is only useful to the manufacturer for the control of the product. The Chapman Jones plate tester with which speed tests are checked consists of a series of strips of varying opacities mounted on a glass plate. Exposures of a certain number of candle-meter-seconds are made through these strips and the resulting densities on the film determined.

Both unperforated and perforated film is produced. The greatest care is taken at all times to perforate film accurately, for unless the perforations are absolutely correct in spacing and alignment, unsteadiness both in the camera and the projecting machine will result. Each machine in the Kodak factory is daily subjected to rigid tests; all guides and punches being carefully examined with gauges which show up to ten-thousandths of an inch variation. A length of film is tested for variation in pitch and is also doubled back on itself to see whether the perforations are uniform or not. Gauge tests are furthermore made for width, and the perforations examined under a magnifying glass to see that their edges are clean-cut and uniform.

The finished film is then wrapped in chemically pure black paper and packed in tin containers which are labeled with the footage length and identification emulsion number, placed in strawboard containers, and is then ready for shipment.

Discussion

Upon Mr. Mayer's request, Mr. Corey showed the Hurter & Driffield curve and explained that the relation of the latitude factor of time to the total exposure time of the plate by over-exposure, varied with every different kind of emulsion, and that he could give no specific value for the average. However, the curve will start down again with very great exposure, giving a positive instead of a negative. In taking an interior with bright windows if it is given too long an exposure, it would be reversed.

Mr. Moulton added that the picture of a bright body against a dark ground will have a halo around it or a dark spot. He supplemented Mr. Corey's remark on latitude by saying that the measurements were taken for direct light and what latitude really means is that within a certain range of practical densities you will get correct relative value for the entire film; whereas, if you over-expose, the high lights will be less dim than they should be; whereas, in under-exposure the low lights will be less dim.

Dr. Kellner mentioned the importance of seasoning a stock by storing it from three to six weeks to take care of shrinkage.

Some discussion then followed between Mr. Richardson, the Chairman and Mr. Mayer on experiences in making film in the warm countries, since film will not stand excessive change of temperature.

Mr. Mayer mentioned the fact that the latitude or exposure curve of the film varies with different portions of the spectrum and did not agree with Mr. Corey on the point that they were working only in the violet portion of the spectrum. Further discussion followed on the effects of climate and length of exposure.

CARBON ARC FOR MOTION PICTURE PROJECTION

By W. C. KUNZMANN

The motion picture theater is a permanent institution as is evidenced by the developments during the past two or three years. Hundreds of motion picture theatres have been built which are second to none of the legitimate with respect to size and appointments of interior and exterior. The productions, too, have kept pace with the theaters. These productions now depict on the screen picture plays costing hundreds of thousands of dollars and employ the best of theatrical talent as principals. The picture producing interests have invested fabulous sums in permanent studios fitted with every conceivable contrivance necessary for the production of practically any play and the innumerable feature incidents which occur in the lives of any and all people of this world.

The art of the motion picture is composed of two principal industries, the manufacturing industry and the exhibiting industry. This paper will describe some of the features of the production of light and its projection through the film as applied to the exhibiting of a motion picture.

The resources available today that answer the general requirements of the light source for motion picture work, that is, steadiness, maximum intrinsic brightness and distribution characteristics permitting a high degree of concentration, are the direct and alternating current carbon arc and the high power incandescent projector lamp.

The carbon arc brilliancy of 84,000 c.p. per sq. in. (130 c.p. per sq. mm.) is sufficient for any condition of operation, while the brilliancy of the incandescent projector lamp approximately 20,000 c.p. per sq. in. (or 30 c.p. per sq. mm.) is only sufficient for low-powered installations at present. This paper will deal exclusively with the carbon arc as applied to the motion picture exhibiting industry.

THE PROJECTION

The projection system optically is practically in the same state of development as the first successful machine. A line drawing will illustrate the important features of the equipment.

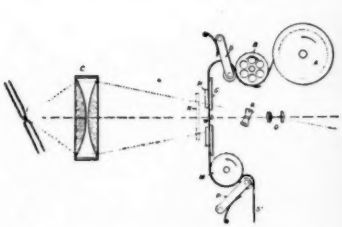


FIG. 1

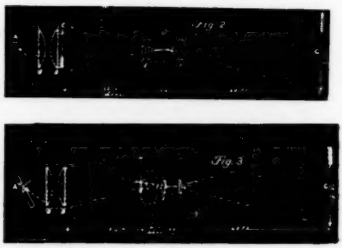


FIG. 2

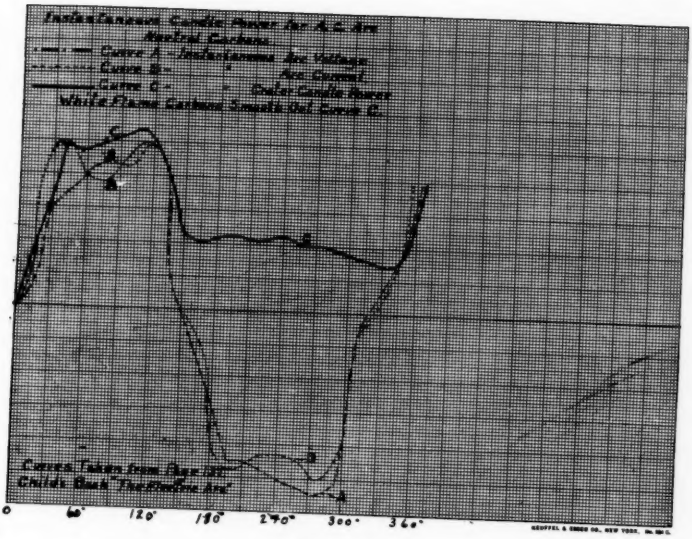


PLATE I.

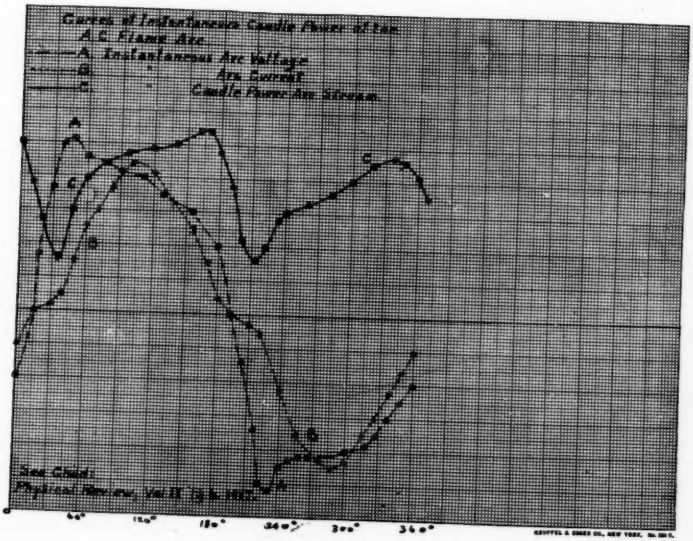

Curves of Instantaneous Candle Power of the
A.C. Flame Arc.
A Instantaneous Arc Voltage
B " Arc Current
C " Candle Power Arc Stream.
See Childs
Physical Review, Vol II

PLATE II.

The light of the arc is gathered by the inner condenser (Fig. 1) into a parallel beam, which is then converged to a spot upon the film. The projector lens is focused upon the film and the light passing the film is then projected upon the screen. The condensing lenses and the projecting lens are independent in size and focal lengths from each other. The former are chosen to best correct the light rays and converge them into the most suitably shaped beam. The projection lens is chosen totally according to the throw and size of screen picture. To get a picture 10 feet wide at 40 feet throw, we merely choose a projection lens having a focal length in inches in proportion to the width of the film picture (roughly 1 inch) as 40:10, that is, 4 inches focal length of lens in this example.

When the projection machine is used as a stereopticon for slides, etc., the projection lens must be of different focal length.

The same principle in calculation is used but now we focus the stereopticon lens on a slide 3 inches wide which is located close to the lamp. Since the same size screen picture is required in both cases (10 feet wide at 40 feet throw) the stereopticon lens must have a focal length in proportion to the width of the slide (3 inches) as 40:10 or 12 inches. (See Fig. 2.)

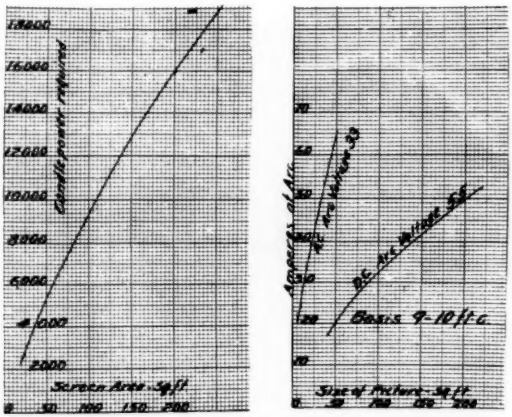


Fig. 3

The Lamp

The entire success of the projection is now up to the lantern and its operation.

The curves in Fig. 3 show the relationship between screen area and the candle power required at the arc, and the current necessary. It is interesting to note that of the total illumination available from the D. C. arc, but 10 percent. gets to the screen, while with A. C. only 5 percent. gets to the screen.

The maximum shown in the curves are no longer maximums but are really minimum values in the better show houses. One hundred am-

peres at the arc for screen areas of 400 sq. ft. are common and even 150 amperes (10 kw.) are being tried. Couple these arc wattages of 7 kw. and 10 kw. with the fact that 60 inch searchlights require only 14 kw. we have some conception of motion picture projection and what it is coming to if present rate of improvement keeps up.

Knowing the amount of current after analyzing theater lighting, screen and equipment requirements, we can select the size of carbons to produce satisfactory screen projection.

Below are given the proper carbon combinations for the different current requirements and also the standard settings for both direct and alternating current projection.

CARBON COMBINATIONS

DIRECT CURRENT

Current	*Size Carbons*
For 25 to 50 Amps. D. C. use	5/8 x 12 inch Cored Upper 5/16 x 6 inch Metal Coated Solid Lower
For 50 to 65 Amps. D. C. use	3/4 x 12 inch Cored Upper 11/32 x 6 inch Metal Coated Solid Lower
For 65 to 70 Amps. D. C. use	7/8 x 12 inch Cored Upper 11/32 x 6 inch Metal Coated Solid Lower
For 70 to 85 Amps. D. C. use	7/8 x 12 inch Cored Upper 3/8 x 6 inch Metal Coated Solid Lower
For 85 to 100 Amps. D. C. use	1 x 12 inch Cored Upper 7/16 x 6 inch Metal Coated Cored Lower

ALTERNATING CURRENT

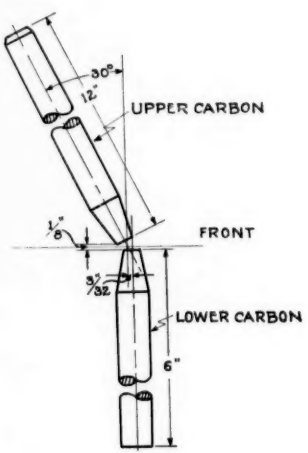
Amperes	*Carbon Diameter*
40 or less than 60	5/8 inch Combination
60 or less than 75	3/4 inch Combination
75 or less than 100	7/8 inch Combination

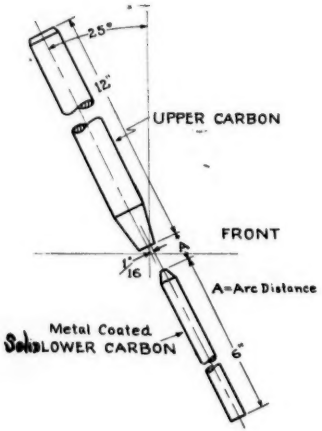
Projector Carbon Manufacturing Process

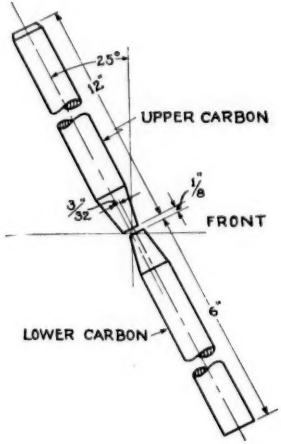
In the manufacture of high-grade projector carbons it is necessary to use an especially prepared carbon flour. The flour is carefully mixed with the necessary binding material and forced by hydraulic presses under high pressure into the desired shape. If a cored carbon is wanted, a steel needle is suspended in the center of the die. The forced carbons are then placed on racks to cool and when sufficiently cool they are cut in the proper lengths for baking. To insure absolute straightness, correct size and perfect stock before baking, the cooled carbons are thoroughly inspected before being turned over to the baking department.

In the furnaces, the carbons are subjected to the temperature necessary to produce a uniform carbon of certain definite prescribed qualities. After the bake is completed, the furnace is sampled and the carbons examined by the testing department before being sent along for finishing. These tests are even more severe than those to which a projector carbon is subjected by the user.

Upon receiving the testing department's O.K., the carbons are sorted for straightness and examined for imperfections, and if they are hollow shells, made ready for coring. Every precaution is taken in the coring department, where the hollow shells are filled to see that the







CARBON SETTINGS

core material fills the entire length of the carbon. The composition of the coring material is of considerable importance as it determines largely the burning quality and color of the arc. After coring, the carbons are dried, finished, pointed, inspected and placed in the shipping stock.

The Carbon Arcs

In the direct current arc, the crater of the positive carbon forms the principal light source. The positive crater is of relatively large area, while the negative spot is small and is not usually considered as a light source. While 95% of the light emitted by the arc comes from the positive crater, the characteristics of the negative carbon are of vital importance in securing steadiness of operation. In operation, the positive crater is set so as to face the axis of the optical system. In setting the carbons in this position, care must be taken to reduce to a minimum the shading of the crater by the negative carbon. In this respect, the direct current arc is superior to the alternating current arc. A direct current arc is longer and therefore gives less shading of the crater. The greatest advantage of the direct current arc is the fact that the current travels only in one direction and therefore the positive crater receives electrical energy continuously and consequently maintains a higher temperature.

As was stated above the characteristics of the lower carbon on direct current are of greatest importance in securing steadiness of operation. The size of the upper carbon is determined by the power imputed to the arc. If the positive is too small the current wil overlap the end of the carbon and the arc will be noisy and unsteady. If too large, the crater covers the end of the carbon and the arc again will be unsteady, because the average temperature at the tip is lower. With the negative carbon, the carrying capacity is the important factor since the size of the negative carbon required by the negative spot is small. A small carbon keeps the arc steady and also eliminates the shadow due to the shading of the crater by the negative carbon itself. This problem has been solved by plating the solid negative over its entire length with a series of metallic coats forming a shell of metal of low electrical resistance around the carbon. This metallic coating volatilizes in the heat of the arc and thus prevents the spattering of the rear condenser lens with the heavy metal beads formed with the old style metal coat. The coating carries the major part of the current and makes possible the use of a small negative with the high currents required by long throws and dense films.

The direct current arc is inherently stable and the range of arc voltage can be made whatever the projectionists desire, but there is one fact to be borne in mind that, for each given current value there is a definite arc voltage at which the arc operates at maximum efficiency. With a constant current value, gradually shortening the arc length, will finally produce an unstable arc; just previous to that point is the limiting voltage for the current chosen. Or, otherwise, a given current requires a certain arc length of voltage. To increase the current and not change the arc length, is equivalent to shortening the arc in the first case and the arc becomes noisy. For this reason increasing voltages are required for increasing currents.

When using small diameter solid metal coated negatives on direct current we start at 52 volts for 30 amperes and increasing by 2 volts for each increase of 10 amperes, reaching 62 for the arc voltage at 100 amperes, a saving of 0.7 kw. or 10 percent. in arc wattage, than in case where the old style large diameter cored negatives are used, starting at 55 arc volts for 30 amperes direct current, and increasing voltage and current in same proportion as recommended in former case.

The arc steadiness and crater formation is materially improved as is shown in the photo (Fig. 4) of equivalent combination in the new and old systems.

In the past when using cored negative carbons the basis for choice of the negative was a ratio of 1 for the negative diameter, to 1.65 for the positive diameter, or a cross-sectional ratio of 1.2.

FIG. 4

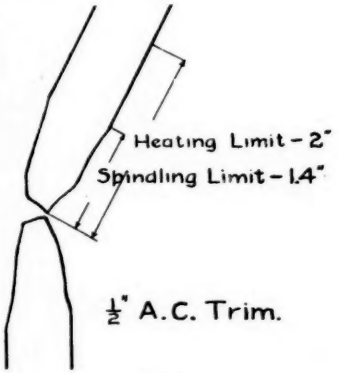


FIG. 5

Under the table of Carbon Combinations for direct current projection, the new developed solid small diameter metal coated negative calls for a cross-sectional ratio of 1.4, the negative having ¼ area of the positive.

What determines the size of a carbon for given service is the ability to stand up under it but the limiting factor differs in A. C. and in D. C.

On direct current the limiting factor is the crater. Since the temperature of a carbon arc is constant just as is the temperature of boiling water—be there a teaspoonful or a barrel full—so, by putting into the carbon more current, we merely increase the number of the hot, light-giving areas until finally the tip of the carbon or crater can no longer accommodate an increase and then no further increase of light is possible for that carbon. The body of the carbon is as yet unaffected by the current but the crater can no longer take care of further increases. This is the limiting factor and so we take the next larger sizes.

On alternating current the crater is but half the size of the crater formation on direct current, owing to the fact that the energy is divided equally between the upper and lower carbon; therefore, we can go still higher in current density on A. C. without reaching a crater limit but we now find that the carbon body cannot carry an unlimited

amount of current without glowing and oxidizing away sharply, so we are limited on A. C. to the physical characteristics of the carbon. Sketch (Fig. 5) shows the physical limitations for a ⅝-inch A. C. carbon. Using the old style alternating current carbon, a short air gap gives a hissing and sputtering arc which is very unstable. By using cored carbons, the cores of which are impregnated with carefully prepared chemicals, an absolutely silent and steady alternating current arc can be obtained. By using the proper chemicals a light source of high intensity is obtained which is far above that of the old cored carbons.

This change in the construction of carbons for use with alternating current projection is one that has come to the front in the last year and has met with marvelous success. It has brought the alternating current arc in close competition with the direct current arc and it has allowed many houses who had seriously considered adopting other sources of illumination to continue with the alternating current arc without necessitating a single change in or about the lamp house or in the wiring. The mere substitution of these new carbons for the old style alternating current carbons makes the alternating current arc a very desirable and economical light source for projection.

In addition to fulfilling the general requirements, the carbon arc has other characteristics which make it adaptable for motion picture work. These characteristics are: 1—Color of light; 2—Reliability; 3—Flexibility; 4—Steadiness.

Color of Light: Until recently, the color of the light used for the projection of the high-class film was a source of much annoyance. It is obvious that where the picture is taken in the open and in bright daylight, the effect upon the screen would be inferior unless the projection light source approached that of daylight in color value. The light of the direct current arc is the nearest approach in color value to daylight of any of the known illuminants that could be used for motion picture projection. The light is a pure white of high intensity. The light of the alternating current arc using the modern high-grade projector carbon approaches that of the direct current arc both in color value and intensity. A pure white light is beyond doubt the proper kind of light to use for projection since it brings out the high lights and shadows and will project upon the screen a picture that will please the most critical audience.

Reliability: The arc in the hands of an efficient projectionist, is a very reliable light source. It is not easily affected by fluctuations in line voltage and therefore will give an even screen illumination where other illuminants will fail. Carbons have a definite length of life and therefore the projectionist can guard against the failure of light in the middle of a reel of film.

Flexibility: The carbon arc gives a steady, flexible light, variable at the will of the operator according to the density of the film. No two films are alike and no two parts of the same film are of the same density and consequently to give a true artistic presentation of any picture you must have a flexible light source.

Steadiness: Both the direct and alternating current arcs are giving absolutely steady illumination. The traveling of the arc and negative

shadows have been eliminated in arc projection.

In conclusion, emphasis should be placed upon the use of proper carbon combinations. The carbon manufacturer specifies a definite diameter of carbon for a definite current requirement and any deviation from this will result in poor projection. If the projectionist is without positive knowledge of the amount of power he is using he can obtain this by means of a voltmeter and ammeter. Standard instruments for this purpose can generally be obtained from the local power plants.

Discussion

In reply to some questions as to the relative efficiency of direct current and alternating current arcs, Mr. Ward said that it took about twice as much power with an A. C. arc to produce the same screen illumination as with D. C. With a small metal coated negative, the arc is steadier and is from 10 to 15 percent more efficient.

Mr. Mott contributed some remarks concerning the new white flame, A. C. carbon. The white flame material in A. C. carbon gives 10 to 15 percent. more candlepower, and since the light is whiter, the acuity is greater. The Navy Department made tests showing that the spectrum of the white flame carbon arc more nearly resembles daylight than neutral arcs.

The crater is hotter and there is more light in the arc stream, owing to the vapor from the white flame material which fills in the time and form deficiencies of the wave form. For this reason the stroboscopic effect is lessened; this white flame arc has the further advantage of being comparatively noiseless.

Mr. Kunzmann said that accurate data is available regarding the proper sized carbons to use under different conditions, and, as this is the secret of good projection, there is no reason why any projectionist should use the wrong trim.

THE PROJECTION ROOM AND ITS REQUIREMENTS

By F. H. Richardson

This article is presumed to deal with the projection machine enclosure, and to set forth, as briefly as may be, some of its more important requirements. It would, therefore, seem fitting that a short resume of the evolution of this enclosure, from a cloth walled affair to what it now is, will not be inappropriate.

In the earliest days of the industry, the projection machine enclosure was usually merely a surrounding drape of black, or dark colored cloth, designed merely to conceal, or partly conceal the apparatus and its attendants from the audience. This form of enclosure continued to be used until motion picture theatres came into existence. The advent of the theatre very naturally suggested a more permanent housing for the projection apparatus, and the need was first met by a wooden-walled room, which, probably by reason of its smallness and the nature of its immediate predecessor, was dubbed the "booth."

Films coming from the projector were run either into an open basket, or a sack attached at its open end to a hoop. This plan was later changed by substituting a large metal tank, which same was made to act as a base for the projection machine itself. Operators (they were little more than mere operators of a machine in those days) were allowed to and usually did smoke at will. The top of the metal tank was often used as a convenient shelf for temporary deposit of red-hot carbon butts, whence one would occasionally roll into the opening of the film tank. As may well be imagined, the combination of a wood-walled room, cigar and cigarette butts and red-hot carbon stubs made for trouble. The resulting fires raised a tempest of very caustic newspaper comment, and the demand for a fireproof enclosure for the projection apparatus. Incidentally it was the tremendous speed of combustion occurring under such circumstances (one and often two reels of film run into a sack or tank in a loose pile) which gave rise to the absurd, but for several years very familiar, "Film Explosion" newspaper scareheads.

The first result of the fires (several of which were rather serious in the item of property loss, and a few in injury to theatre patrons, the latter resulting almost entirely from panic) was an attempt to fireproof the enclosure by covering its walls with sheets of either tin or iron. This proved highly ineffective, and was later ordered put on with locked joints; still later the metal covering was backed with sheet asbestos.

Some very amusing instances of official stupidity occurred in connection with the early attempts at fireproofing. Chicago had just passed an ordinance requiring the interior of all picture shows located in buildings in which families lived, to be fireproofed with pressed steel, backed by sheet asbestos 3-8 of an inch thick. An inspector visited a North Clark Street "store room" theatre, on one side of the auditorium of which was a 24-inch brick wall, finished with plaster ap-

plied directly to the brick. He actually threatened to close the show unless that wall be immediately fireproofed as per ordinance.

Gradually these makeshifts were improved upon, however, until we have today many examples of really very fine projection machine enclosures, though there is still a sad lack of any generally applied adequate standard as to either size, construction, or other items, and it is for the purpose of supplying a basis for these standards this article has been undertaken.

In the beginning of the industry there was slight need for any other than very rudimentary knowledge or skill in projection. Motion pictures were a novelty, and people paid to see them as such. Projection machines were small and their workmanship crude. The illuminant was weak. The photography was poor. The perforations were anything else than accurate. The screen was merely a square of muslin, and as long as there was something resembling a motion picture somewhere on the front wall of the auditorium, everyone was well pleased. Technical knowledge, as applied to projection, simply did not exist. No one gave the "booth," or what it contained, a second thought, except to abuse the "operator" when he stopped the show too frequently to mend broken film, run too long out of frame, or requisitioned too many repair parts. The projector enclosure was placed in any space within sight of the screen which could not possibly be utilized for anything else. It had neither ventilation, nor toilet facilities. It was made the subject of a flood of absurd rules and laws, formulated by men who knew absolutely nothing about the real requirements. It was, literally, the very last thing to receive consideration as the industry advanced, and years of vigorous fighting were required to bring theatre men to a realization of the fact that the room from whence the picture is projected lies close to the very heart of things.

The business of the projection of motion pictures had to be literally dragged up out of a mire of almost contempt, and established on a plane of respectability. That recognition to which its importance justly entitled it had to be fought for, and has been partly won, but the battle is not yet over. I venture the assertion that the future will see the projection of motion pictures accorded recognition as of equal importance in artistic possibilities with any other branch of the industry, to say nothing of enormous possibilities for economy through accurate knowledge and intelligent handling of the mechanical, electrical and optical details of projection installations.

To dispute the proposition that the room we are about to discuss is the very heart of the motion picture theatre is equivalent to contending that one plus one does not make two. When the producer, his directors, high-grade camera men, high-salaried artists, dozens and maybe hundreds of lesser lights and his dark-room men and assemblers have all done, the finished product, be it the "Battle Cry of Peace" or the humble efforts of the screen "Barn-Stormer," must perforce be turned over to the man in charge of projection for reproduction upon the theatre screen before the final judge, the public. And who will dare say that poor equipment, poor working facilities or lack of skill will not either almost entirely ruin, or at least largely detract from the artistic value of the finest production ever made, thus largely impair-

ing its effectiveness with the audience? And if this is true, does it not follow that the projection machine enclosure, including its contents and the men in charge, are of huge importance to the industry?

For the foregoing prelude I make no apology. If there is objection to space consumed, just consider the amount of space used up during past years on subjects of far less importance to the industry, and hold your peace.

To begin with, the writer very seriously objects to the name given the projection machine enclosure, namely, "booth." Webster, who is presumed to know what is correct in words and language, tells us a booth is a "temporary structure of boughs; a shack."

For many years I have used the name "operating room." This, however, while a very decided improvement over "booth," does not quite fill the bill. It seems to me that, logically, the room from which pictures are projected is a "projection room," and the writer respectfully suggests to this body its adoption by the department of nomenclature. It will be hereafter used in this article.

The only possible objection to the use of this name is the fact that some theatres and producers have applied it to the room where pictures are screened for examination. Such rooms are, however, properly either "exhibition" or "screening" rooms, and that a misnomer has been applied should not, I think, prevent applying the logically proper name to the room from which pictures are projected.

Structure: The projection room must have fireproof walls, floor and ceiling. The floor must be solid and free from vibration, as any vibration communicated to the projectors will inevitably affect the screen result. For the floor I would, therefore, suggest not less than four, and preferably six inches of the usual mixture for "rich" concrete, the stone to be not larger than will pass through a one-inch screen. Over this should be a one-inch top dressing, guaranteed not to disintegrate into dust. Many cement finish floors show this fault, and it is a very serious one, since the dust gets on the films and into the delicate machine parts, where, due to its nature, it acts as an abrasive and does great, though slow, damage. For this reason I would suggest that the top dressing might better be tile, similar to that commonly used for bath room floors. If cement is used, it should be treated to an acid bath to harden its surface. Such a bath is available, but its application would very nearly make the cost of the cement finish equal to that of tile, and tile is much to be preferred, from any and every viewpoint.

NOTE.—Since the foregoing was written I am informed there is a varnish which is giving satisfaction in generator and other rooms in which this fault has been experienced. This matter will be looked up and the name of the varnish announced through the usual channels later.

In wall and ceiling construction, there are the following points to be considered, viz: fireproofing, soundproofing, rigidity and lack of heat-absorbing and retaining qualities.

For permanent installations there is nothing that so well fills all these requirements as six-inch hollow tile, set in, and plastered on both sides with rich cement mortar. Such a construction is, by com-

parison with brick or concrete, light in weight (an important consideration in some circumstances), quite thoroughly soundproof by reason of its interior air space, sufficiently rigid for all practical purposes; also it neither absorbs nor retains the heat to any appreciable degree. Hollow tile is, therefore, the best possible medium for projection room wall and ceiling construction. Four-inch hollow tile may be used for the ceiling, but six-inch is best for the walls.

Next in order of excellence is concrete. The objections to this material, as compared to hollow tile are threefold, viz.: excessive weight, absorbs and retains heat, and, unless of considerable thickness, acts to some extent as a sounding board to distribute sound inside the room out into the auditorium.

Following concrete comes brick. Its objections are weight, cost, heat-absorbing qualities and difficulty of ceiling construction, where same is necessary.

For permanent installations what is known as the asbestos room should not be considered at all, except its present construction be radically changed. As at present made its ceiling is not high enough; also, its walls and ceiling act as veritable sounding boards for the distribution of sound, though it forms an acceptable fireproof room for strictly temporary installation. With double walls and ceiling, with an air space between, and an eight or ten-foot ceiling height, it would serve very well for permanent use.

Dimensions: It is not to be reasonably expected that the projectionist will do his best work if placed in crowded, cramped quarters. Space inside a theatre is valuable, especially if it can be utilized for seating, hence exhibitors begrudge every inch surrendered, and usually try to reduce the projection room to its least possible dimensions, which is extremely poor policy, when carried to the point where projection is made to suffer. So far as the writer knows, up to date every legal standard set up for size calls for a too small depth, front to rear.

The shortest of modern professional projectors measure four feet three inches front to back when setting level; considerably more when at an angle. The setting of projection machines up against the front wall is poor practice. There should be at least 18 inches between lens and wall when machine sets level, and not less than three feet in the clear behind the projectors. Taking everything into consideration, nine feet may fairly be set up as a standard front to rear depth for projection rooms, with the notation that ten feet is better.

The width of the room should be a minimum of six feet for one machine, with three feet of added width for each additional projector, spot lamp or stereopticon. The minimum distance from the floor to the ceiling should be eight feet, with the recommendation that added ceiling height be provided where possible. A high ceiling is very desirable, both from the viewpoint of health and comfort and in case of fire, since it provides a reservoir for the heated air above the heads of the men, and for gases and fumes, should a fire occur.

Ventilation: This is indeed a most important item. Let it be first understood that pulling the fetid atmosphere in from the top of a hot auditorium through the projection room ports does NOT constitute ventilation. The projectionist is human, and it is nothing less than a

crime to compel him to breathe such air. First, there must be vent flue in the ceiling, or in the wall at ceiling height, leading directly to the open air, and this vent should be of metal, with locked joints. It should have an inside diameter of eighteen inches and should be thoroughly insulated from all wood work, since it is apt to become very hot in case of fire. In this pipe, should be installed an electric fan not less than 18 inches in diameter, so wired that while its speed may be controlled by the projectionist, it cannot be stopped while the projector is running; also the wiring should be so arranged that the dropping of the fire shutters will automatically start the fan going full speed, in case it is running slowly. This latter is of the utmost importance as an adjunct to fireproofing, since in case of fire, unless the smoke and fumes be pumped out, they will or may filter out into the auditorium, where-

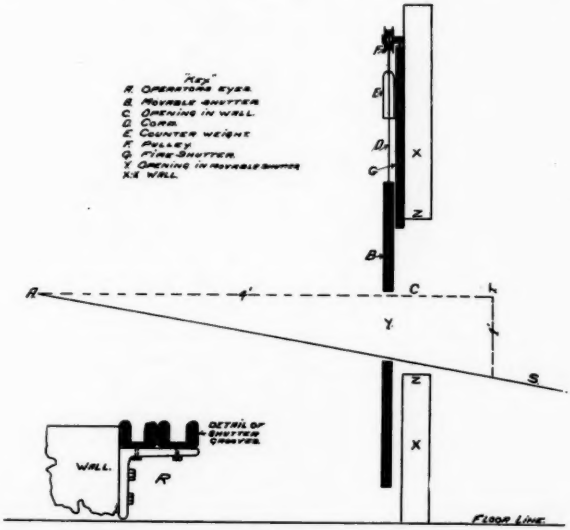


FIG. A

Sectional detail of adjustable observation port shutter, with special detail showing construction of channel iron grooves for same.

upon the inevitable cheerful idiot will yell, "Fire!" and you all know what happens then. Second, there must be one or more fresh air inlets at or near the floor line, leading directly from the outer air. In this connection, I would recommend the Massachusetts law, which requires a fresh air inlet not less than 15 inches long by 3 inches high on each of the four sides of the projection room, same to be located not more than 2½ inches above floor line. There should also be an inlet in the center of floor, if possible, otherwise in center of rear wall, not more than 2½ inches from floor, same to have an area of 160, 200 and 280 square inches, respectively, for one-machine (six feet wide), two-

machine (nine feet wide) or three-machine (12 feet wide) room. The same law requires a twelve, sixteen, or eighteen-inch vent pipe, respectively, and fan for different size rooms, but with this I am unable to agree, since a burning film will make just as much smoke and fumes in a small room as in a large one. Eighteen inches should, in my opinion, be the absolute minimum diameter for projection room vent flues. Third, all lens and observation ports should be covered with glass in order to prevent the pulling in of foul air from the auditorium as well as to prevent smoke entering the auditorium in case of fire. The inlet fresh air ports should be provided with shutters, arranged to automatically close in case of fire, when the port shutters are dropped. The dropping of these shutters will compel the exhaust fan to suck air in around the cracks of the port shutters and door, thus preventing any smoke from seeping out.

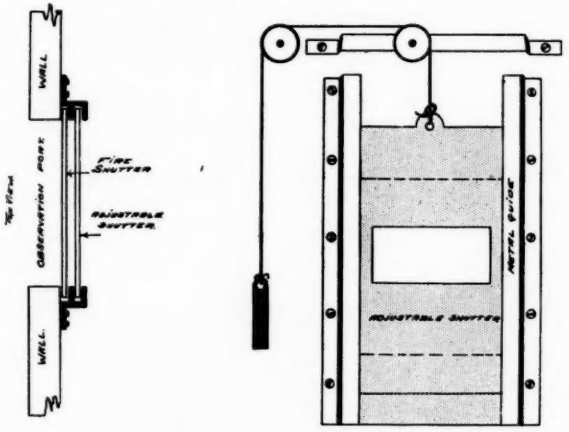


FIG. B

Showing elevation of adjustable shutter, and detail of its relation to the regular port fire shutter.

Sanitation: It is absolutely essential that the projection room be applied with toilet facilities. This is so obvious that argument should be and is, I think, unnecessary. There should also be a wash bowl, with running water. The projectionist's hands become soiled with oil and carbon dust, and it is better to wash this off with water than to wipe it off on films worth $125.00 per reel—yes, quite considerably better.

Observation and Other Ports: This is an extremely important item, and one subject to great abuse. It is utterly absurd to expect a projectionist to put on a high-class reproduction of a photoplay if he must squint at it through a sort of glorified knot hole. *It is absolutely essential to high-class projection that the observation port be of size sufficient to allow the projectionist a full view of his entire screen from ordinary projection position.* The position of the observation port as to height from the floor will depend, of course, upon projection pitch. I have always

recommended, and do still recommend an opening in the projection room wall 12 inches wide by 24 inches high, same to be covered with a sliding shutter, hung on a counter weight moving up and down at the will of the projectionist. In this false shutter there should be an opening ten inches wide by six high. By this plan, we have a port six inches high by ten inches wide, adjustable as to height over a range of 24 inches. Such a port shutter is illustrated, Figs. A and B. Its construction (too lengthy to be incorporated herein) is described in detail, pages 218 to 220, inclusive, Richardson's Motion Picture Hand Book for Managers and Operators. All lens and observation ports should be covered with glass, as already set forth. Lens ports should be no larger than is necessary to pass the actual effective projection ray.

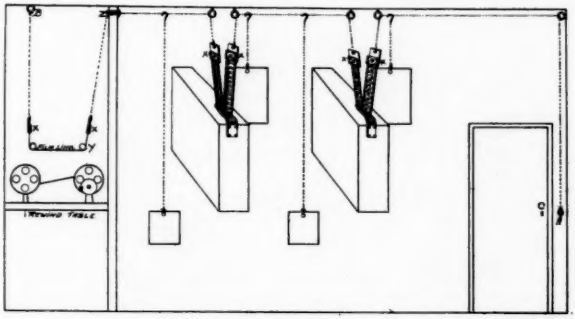


FIG. C

Showing method of suspending individual shutters from one master cord. This may be and is done by means of patent devices which serve the same purpose, but are in reality little or no better; in fact they may be not so good, since by their use the fuse link is almost invariably located a considerable distance from any possible seat of fire. As in this illustration it is the *idea* which is illustrated, its practical application varying with the individual installation.

Position of Projection Room: This is a subject so well understood that its discussion would be largely a waste of space, except to say that it should never be less than 50 feet from lens to screen, if a picture twelve feet or more in width is to be projected. Its permissible height above the screen has already been taken care of acceptably by this body.

Port Shutter Fuse Links: It is, of course, necessary that all ports be covered with shutters of fireproof material, so arranged that they will fall automatically in case of fire, *and do so within a very few seconds of the starting of the fire;* also, so arranged that they may be instantly dropped by the projectionist. The usual present practice in location of fuse links renders them of no practical value. I have for years recommended the substitution of links of film for metal fuse links, and have insisted that they be placed as closely as possible to every probable seat of fire. As I have repeatedly pointed out, it is imperative that the fire shutters drop within 5 seconds of the start of a fire, else they might almost as well be left up altogether. It is not the fire which works in-

jury to an audience. With a modern fireproof projection room it is practically impossible for fire itself to work injury to any individual of an audience. It is the resultant panic when some one invariably present where an audience assembles, sees smoke or fire and spreads the alarm at the top of his voice, usually accompanying it by a rush to the door. In view of this fact, it would seem advisable either to do away with fuse-links altogether, educating the projectionist that the first act when fire occurs is to drop the shutters, or else adopt a better-placed, quicker acting fuse. Some idea of such fuse-links are shown in Figs. C and D.

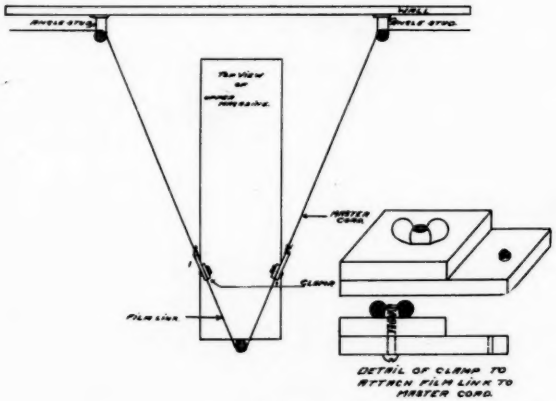


FIG. D

Showing detail of film link to be placed immediately over projector aperture, where fire will strike it very quickly. A still better plan is to cut a narrow slot in front of upper magazine, at front, near top, passing a link of this film-fuse through same into magazine with a bit of wire thrust through to hold same, so that when fire strikes it fuse will be released instantly. There are so many ways of accomplishing the end that in this paper space will only admit of the *idea* being conveyed. The best method of application, remembering the main idea is to secure instant severing of the link when fire starts, must be left to the individual to work out.

Equipment: I think it is unnecessary to deal with the equipment of the projection room in this paper, since it could by no stretch of imagination be made the subject of standardization, as an equipment; though its parts should have attention.

Projectionist: There is, however, one subject further which, it seems to me, deserves notice; viz.: the title of the man in charge of the projection room. The term "operator" is nondescript, non-descriptive and not at all in keeping with the business of projection of photoplays. We have telephone operators, telegraph operators, etc., etc., almost without number. Presumably we call the man who projects pictures an "operator" because he operates a motion picture machine. By precisely the same logic, the locomotive engineer is an "operator" because he operates a locomotive, and the organist is an "operator" because he operates an organ.

If a man merely attends to the mechanical operation of a machine which does the same work in the same way constantly without opportunity for initiative on the part of the person in charge which will alter and change the finished result, then I grant you the man in charge is merely an operator of the machine. But who will say the locomotive engineer, the organist, or the man in charge of projection does no more than this! As a matter of fact, the latter must have initiative along several lines, as well as a wide knowledge of electrics, optics and mechanics. The man who projects pictures is logically, it seems to me, a "projectionist." That title is descriptive, appropriate, and, at least in some measure, dignified. I would, therefore, suggest to the Department of Nomenclature the word "Projectionist" to designate the man who projects pictures, in lieu of the present inappropriate term "operator."

NOTE.—Since this paper was prepared and read the Society has, by unanimous vote, adopted the term "projectionist" as designating the man who projects motion pictures professionally.

DISCUSSION

After Mr. Richardson's paper some general discussion followed on the preference of the term "projectionist" for operator. The question of some arrangement to enable the projectionist to see the scene and know whether the picture is in focus or not was taken up. Since it is impossible to view a picture while standing in a bright room, two methods of overcoming this difficulty were suggested. In some theatres, the cone of light is hooded leaving the room dark; in other theatres, a glass port hole is used with a hood painted black inside.

Sanitary conditions in the operating room were touched upon and the statement made that six hundred (600) operators die annually from pneumonia. Mr. Kunzmann said that while much of this was attributed to carbon fumes, that experiments had been made proving that there was nothing in the carbon fumes or the air in the projection room to injure the projectionist, if the room was properly ventilated.

It was recommended that every port hole including that through which the beam of light passes to the screen be covered with glass to prevent the impure air from the top of the auditorium coming into the booth. Dr. Kellner places the loss in light, if the port hole through which the beam of light passes is covered with glass, to be from 8 to 10 percent.

NATURAL COLOR CINEMATOGRAPHY

By WILLIAM V. D. KELLEY

On several occasions upon being attracted to a theatre where color motion pictures were advertised we were disappointed upon finding them to be black and white hand-colored films. There is, therefore, a rather small difference, in words, between the films that I have started out to discuss and the other films with a similar name.

Color motion pictures may be said to be the usual type of black and white value films arbitrarily colored with dyes by means of stencils or hand work and painted to suit the individual taste.

Natural color motion pictures for the moment and until a more distinctive description is given to the title, may be understood as being those photographed so that the colors are selected entirely by optical and mechanical means and reproduced again in a like manner. It is this type of film that I am to discuss with you.

The subject is a massive one and as I have not the time this year to go into details as to the *modus operandi* of each of the steps involved, this paper is simply an attempt to introduce the subject broadly with the hope that the several other color workers in our Society, and the many members, not immediately concerned but who have shown that they are intensely interested in the subject, may continue the work at subsequent proceedings of the Society.

STANDARDS

A successful commercial film in natural colors should meet our Society's standard in one respect:

Film Speed.—A film movement of 60 feet per minute through motion picture mechanisms shall be considered as standard speed. (Standards adopted S. M. P. E.)

Other standards already listed and which help to make for advancement in this color field:

(*a*) Frame Line. (Standards adopted S. M. P. E.)
(b) Perforations. (Standards adopted S. M. P. E.)

PROJECTION

Probably all projectors in use today throughout the world are designed to operate at a film speed of 60 feet a minute with but small latitude for satisfactory operation at higher speeds. In order to enjoy to the fullest a commercial success and to give to the greatest number the enjoyment that color lends to so many subjects, we must first meet this requirement and produce a film capable of giving its best on these machines.

Such films may be combined with the black and white subjects; joined, cut, assembled and in general behave so that the projectionist customarily handling film can use them without special instruction or training.

Commercial positive films are those in which each image area is substantially complete as to color rendering. The colors are in the film in the form of dyes, metals or other color compounds. The black and

white records may or may not exist, depending on whether the films are constructed on the additive or subtractive methods.

Each alternate image area may vary in its colors so that the fullest color rendering is only obtained on projecting. For example, each alternate color-image may be a representation of the Reds and Greens, while the second set of alternating images may be a record of the Orange-Yellows and Blue-Violets. The colors fuse or combine when projected.

We are nearer to a successful realization of this form of color film than many of you are aware, and it may be of interest to point out a few of the suggested or attained methods.

(*a*) *Single Coated Emulsion.* Two or three-color images are impressed in the gelatine. Usually one of the color-images is the result of the silver in the original emulsion, with the second color-image obtained by means of a sensitive bichromate salt. If a third color-image is to be impressed into the emulsion in register with the first two, it may be applied by imbibition.

It is quite possible to get the two colors in the single emulsion. I have done so, in projectionable lengths. There are certain obvious drawbacks, however, from a commercial aspect.

(*b*) *Two Emulsions on One Side.* The first color-image may be a blue tone in the original coating. A second emulsion is then coated over the first one, printed, and the silver converted to a red color by toning or otherwise. I have seen reels of film produced by this method that appeared to be satisfactory, but I understand that there are manufacturing difficulties. It always seemed as though it was too long a wait, after finishing the first color-image, sending the film back to a red lighted coating room for a new coating, a new printing and development and a second coloring before determining if everything had gone right on the first tone. Not to speak of the added difficulties of registration due to alteration in length, the expense of making short lengths and so on. (The Fox system follows this procedure.)

(*c*) *Double Coated Emulsion.* Here we have a celluloid base with a silver emulsion on each side. Both sides are printed before development. If on a two-color basis, all of the red value pictures are printed on one side and all of the green value pictures on the opposite side in register, and after development the black images are converted or transposed into color-images. This process is "healthy" and will, doubtless, be the first to reach the market in some form or other.

(*d*) *Single Coated Emulsion.* The celluloid base is colored in fine dots or lines. In one method published, the celluloid is passed over suitably engraved rollers and fine ridges impressed in the base forming hollow spaces, similar to the raised portions on the opposite side. These depressions are filled with colored inks, red on one side and green-blue on the other. Variations provide for 3 and 4 colors. The emulsion must be color sensitive and the negative printed with colored lights or their equivalent. (See Dufay U. S. Patent No. 1,155,900.)

Some other developments are not far enough advanced for me to give you a description now Those described will serve to show you the general direction of the work. Many of these and similar ideas were discussed or described seven or eight years ago, but the difficulties of

producing on a commercial scale crop out in unexpected places, thus delaying the progress of the industry.

Coloring

Two methods of coloring films are as follows:

First: Those in which the color separation images are in black and white, representing the Red and Green values alternating throughout the length of film. The entire image area of the Red value pictures are dyed that color over the black records and the same for the Green records. The pictures may be projected at high speed to overcome the pulsation of the colors, or on a special machine which exposes two images at one time and superimposes them on the curtain. This system is not adapted to present standard methods of projection.

Second: The conversion of the silver images to color is one means available if the pictures are to be produced on the subtractive basis. This method gives us clear gelatine in the whites, the black being made up of a full density of the colors used. The print from the red negative is colored its complementary color green-blue and the print from the green-blue is colored red.

Broadly—the silver is converted to a salt or a compound capable of holding dye.

(*1*) Traube, U. S. Patent No. 1,093,503 of 1914. Silver converted to silver iodide, dyed, and the more or less opaque iodide removed. Uses basis dyes.

(*2*) Miller, U.S. Patent No. 1,214, 940 of 1917, produces a transparent mordant by treating the silver image in iodine, and potassium iodide. This fixes basis dyes.

(*3*) Wm. F. Fox, U. S. Patent No. 1,256,675 of 1918, provides for toning by Ferric Salts for the Blue and with Uranium for the Red.

(*4*) W. I. Crabtree, The Photographic Journal, August, 1918. Toning with Copper to provide a mordant for basic dyes.

The following is just the reverse of the above. The dye goes into the clear untanned gelatine.

(*5*) J. G. Capstaff, English Patent No. 13,429 of 1915. The silver image is bleached and tanned so that the dye goes into the gelatine in proportion to the amount of silver that was present. A negative gives a negative. So it is necessary to use a positive print in order to obtain a dye positive. This process is known commercially as Kodakchrome.

Negatives

As in black and white photography, you must "get it in the negative" before it is possible to get it on the screen in anything like natural colors.

The camera controls these vital questions:

(*e*) Exposure

(*f*) Fringing (Result of rapid action where single records are made successively.)

(*g*) Parallax (Result of taking through multiple objectives so that portions of the view do not register.)

The suggested or tried methods for overcoming parallax and fring-

ing are numerous. The photographing of all of the color records at one time is the obvious means. A single objective must be used if the views are to be free of parallax. The use of two or three objectives with multiple exposures is feasible in overcoming fringing, but introduces parallax.

Campbell (English Patent No. 2,786 of 1913) suggests a way of using multiple lenses and overcoming parallax by blurring the portions that are "out of register" and the scheme appears workable, the main drawback being the fact that the short focus lenses usually employed for cinematograph work cannot be used.

However, the camera employed to date by one company takes negatives in which the pairs of records are in sequence on a single strip film taken singly without parallax and it is a fact that 95% of the negatives are without noticeable color fringe. Color fringe is due to the fact that successive stages of the action do not register as regards color, a moving white object particularly being preceded and followed by stripes of pure color when projected.

It seems to me that a camera taking single records at each exposure satisfies the commercial aspect, especially as the negative is workable in connection with the commercial positive film.

The negatives are photographed through gelatine color filters and in the two-color system consist of blue-green and red-orange so that one record is made through blue-green followed by a record taken through the red-orange. It requires both of these records in each frame of positive to make up our complete color record of the commercial (16 pictures per second) film. Consequently twice the footage of negative is required in recording the scene as compared with black and white negative of the same scene and this holds good with all systems or schemes with the exception of the "d" (Dufay) film mentioned above.

Exposing 32 pictures a second through color filters is some job too. However, an increased exposure period in the camera plus a very important improvement in the filters makes the work quite practicable.

Filters

These are colored gelatines, usually mounted between two optically flat glasses. They have the property of passing certain colors and absorbing certain other colors. A complementary pair of taking filters will, for example, allow the orange and red to pass through one of the pair and record those values on the film in the final form of developed (reduced) silver, while the green and blue light reflected from the objects being photographed will pass through the green-blue filter. This explanation, however, is only partially true, as the conditions only hold good at certain intensities of light. Either of the filters in the pair will record white light and will pass red-green and blue light if of sufficient intensity. It is this necessity of recording the whites and greys and still preserving the separation or isolation of colors that is responsible for the Raleigh-Kelley Patent U. S. A., No. 1,217,425 of 1917.

By this means, to each exposure through the color filter is added on the same image area a neutral exposure which has very much the same effect as the addition of the grey print in quadricolor printing, and while this about doubles the exposure, it is also found to wonderfully

enrich the picture with pastel shades such as are found in nature. It helps to furnish detail and round out the picture.

Printing

All color record negatives are in sets of from two upwards. Therefore, the simplest form must use two records, separated in some manner. Aside from the "d" method described under "Positives" some suitable means must be found for bringing the records into register.

Most of the appliances are optical and those interested can look up the Brewster U. S. Patents and the Capstaff English patents for descriptions of their methods. Fox of Kinemacolor uses a still different optical form, which is virtually two printers, facing each other. One feeds the negatives two image areas while the other feeds the positives one image area, so that the records of one color follow each other in close sequence on the positive. The negative is illuminated and projected by a lens system to the positive. The same operation is followed for the second color. Prizma prints by contact, depending on the sprocket holes. Absolute registration must be had on the positives, for if this is not secured the pictures will not appear sharp and clear, even though the lack of registration is not otherwise objectionable.

Productions

Probably very little work has been done abroad during the past few years with color cinematography. In the United States several groups are busy with the problem and some have reached the market or have been given public showings.

Kinemacolor gave up its wheel screen showings and devoted itself to perfecting the Fox process, which is covered by description under "B" heading above.

Technicolor two-color taking process. Camera records two color value records of each exposure, simultaneously, but not adjacent through one lens. Rapid movement resulting in fringing is therefore eliminated. Public showings were on a special type of projector which superimposes two images on the curtain at one time. This process appears to be technically correct, but is not adapted to standard projection in its present form.

Cinechrome two-color taking, two adjacent images being recorded at each exposure. Projection by means of a special projector superimposing two images on the curtain at one time, eliminating fringing and pulsation. Very much the same as the Technicolor process.

Douglass two-color taking records being made singly in succession and projected in that way at high speed. Does not use color wheel, but dyes the red positive record red and the green-blue positive record green. Public showings in New York did not indicate any improvements over similar methods showing before its advent.

Kesda. Working on a method for producing a film that projects at sixteen pictures a second—standard.

Prizma. Double complementary pairs of images used in taking. One pair records the red-orange and blue-green values, the second pair records the orange and blue values. (See description under "Filters" for an added feature used in making the negatives.) Their new positions project at 16 pictures a second—standard.

In addition to the above the Eastman Company possesses the Chronochrome process of Gaumont using three colors in taking and projecting. Members of the Eastman staff have also developed a commercial process, in which double coated positive stock is used and the dyeing applied by the (5) Capstaff process described above.

Patents

In England the patents for steps useful in color cinematography are several hundred, while France and Germany have done their share. In the U. S. we have the grand-daddy of them all—Mr. F. E. Ives, issuing frequent patents on this subject. Several others are mentioned in this paper, but it is too big a subject to cover now

Some inventors anticipating the direction that this work would ultimately take have endeavored to cover up by patents the principles that would apply. They have been more or less successful in this, but as it is a lifetime work for any individual to have covered all the steps, some patents wait for the art to grow up to them.

Future

I quote from "Photoplay," for September, 1918.

"Imagination's one expression is art, in some form or other. What music has meant to Italy, painting to France, the novel to Russia, and dramatic literature to England, the moving pictures will mean to America.

"Yesterday America was the only believer in the moving picture; today it is the only developer; tomorrow it will be the only master of the craft."

Up to the present we have lacked the paint brush and palette. No motion pictures in natural colors approaching the possibilities of this art have been shown. No artist has had his opportunity. Motion pictures, grander and more perfect than those paintings adorning the museums of the world are in store for the world, in motion. I have seen the "signs" and know that they are near.

Discussion

Mr. Burrows asked just how the colored image on the film was obtained.

Mr. Mayer, by way of illustration, showed samples of the double emulsion process film—emulsion on both sides of a celluloid base. In the negative, one frame is taken through a green filter suppressing the reds; the corresponding frame is taken through a red filter suppressing the green. From this negative, the print is made with one color value on one side and the other color value on the other side, and is then dyed in order to render the field of transparency on one side, a match-up with the color on the other side. In other words, the negative separates the color values and the color is restored by superimposing the prints of the various color values. Then followed a brief description of different methods of taking these negatives and the advantages and disadvantages of each.

THE FUNCTION OF THE CONDENSER IN THE PROJECTION APPARATUS

By HERMANN KELLNER

Light radiates from every point of a source in all directions. If we had a very intense, and at the same time cold, point-shaped source, projection would be possible without any additional optical apparatus. Supposing we have such a source *s* separated by the distance *d* from a stencil *t* and at a distance *D* from the projection screen, the size of the image on the screen would be $\frac{D}{d}$ times the actual size of the Stencil or, differently expressed, the magnification $M+M=\frac{D}{d}$. The magnification may be changed in two ways:

(a) By keeping the projection distance *D* constant and varying the distance between source and stencil.

(b) By keeping the distance *d* the same and varying the projection distance.

The illumination on the screen is more favorable with the shorter projection distance, because a greater amount of the radiation from the source is utilized. The illumination in the center of the field is inversely proportional to the square of the distance *D* of the screen from the source. For points outside of the center of the projection field the illumination is less than in the center. If *a* be the angle from the source to a point of the field distant the length *b* from the center, the illumination *i* at the point will be proportional to the cosine and the square of the sine of that angle and inversely proportional to the square of the distance from the center of the field to the point.

$$i=\frac{\cos a \cdot \sin^2 a}{b^2}$$

To utilize more of the radiation from the source, we apply a condensing system, which takes in as large as possible a solid angle of the radiation from the source, and forms an image of this source at which the rays forming this image meet under a smaller angle or, more generally speaking, under an angle which is more suitable to the particular conditions of the case than the large angle of radiation taken in by the condenser.

By combining an optically perfect condenser, *i. e.*, a condenser which forms a point-shaped object, with a point-shaped source of great intensity, a very simple and perfect projection apparatus could be realized, which would need no projection lens and which would utilize a greater percentage of the energy radiating from the source than the condenserless arrangement. For example: In figure 2, *s* may be a point-shaped source and the distance between *s* and the condenser *c* may be shorter than the distance from the image of the source *s'* to *c*, so that the aperture of the condenser appears under a greater solid angle from the light source than from its image. If we assume

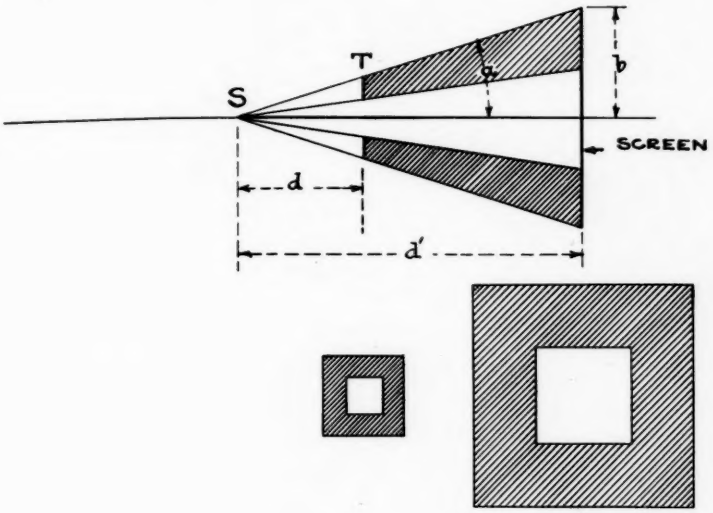


Fig. 1

Projection of the stencil T by means of a point shaped source S. The picture on the screen is the shadow of the stencil.

the geometrical conditions on the image side of the condenser (location of stencil, angle under which the boundary rays meet at the image s', projection distance, etc.) the same as the conditions in figure 1, we will have a perfected image of the same size for the same projection distance, but with better illumination, because a greater solid angle of the radiation is intercepted by the condenser and made useful for the projection than is intercepted by the stencil in figure 1.

The image s' can be considered in its effects like a real light source, with the difference that it radiates only within a limited solid angle, the apex of which is s' and whose base is the surface of the condenser.

The amount of radiation taken in by the condenser is proportionate to the square of the sine of the angle u between the optical axis and the ray through the margin of the condenser (which is half of the total angle taken in by the condenser). If, for instance, the size of the stencil in figure 1 were 3" x 2¾", the diagonal would be with close enough approximation=4". Assuming a magnification of 10 at a projection distance of 113.4 inches, the resulting useful angle of radiation at the source would be 20°. If by using a condenser of suitable power, we intercept a larger angle of radiation while keeping the angle at the image the same, we will have an increase of illumination proportionate to the square of the sine of half the angle at the source. The amount of such possible increase may be seen from the following table:

Full angle $2u$ at source	Half angle u at source	sin u	sin $2u$
20°	10°	0.174	0.03
40°	20°	0.342	0.12
60°	30°	0.500	0.25
80°	40°	0.648	0.42
100°	50°	0.766	0.59
120°	60°	0.866	0.75

If we increase the angle u in our example from 10° to 20°, 30°, 40°, we shall have a relative illumination on the screen proportionate to 0.12, 0.25, 0.42 against 0.03, or taking the latter as unit, an increase of illumination of 4 times, 8.3 times, 14 times over the original case. This consideration does not take into account the loss by absorption and reflection in the passing through the condenser of the light.

Even though by use of the condenser we utilize a greater amount of

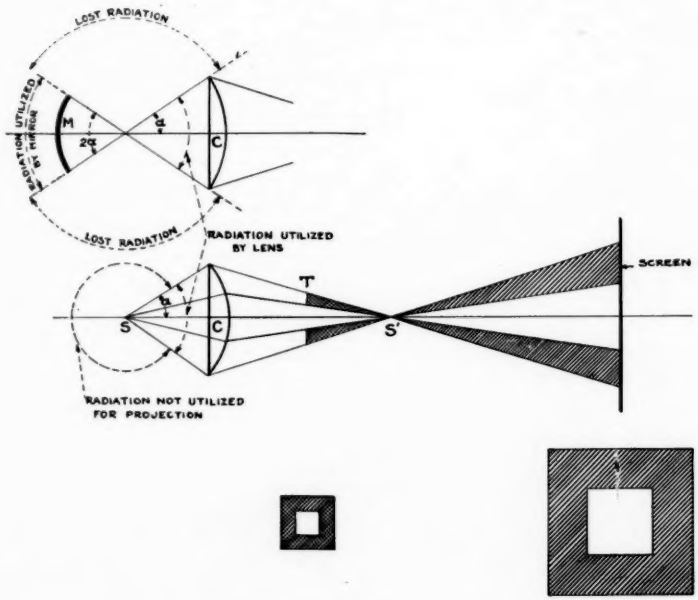


Fig. 2

By interposition of an optically perfect condenser C, the illumination on the screen can be increased, because a greater solid angle of the radiation from the source S is utilized for producing a picture on the screen of the same size as shown in Fig. 1. The upper figure shows how by placing a spherical mirror with its center curvature in coincidence with the light source, the quantity of light reaching the lens can, at least theoretically, be doubled.

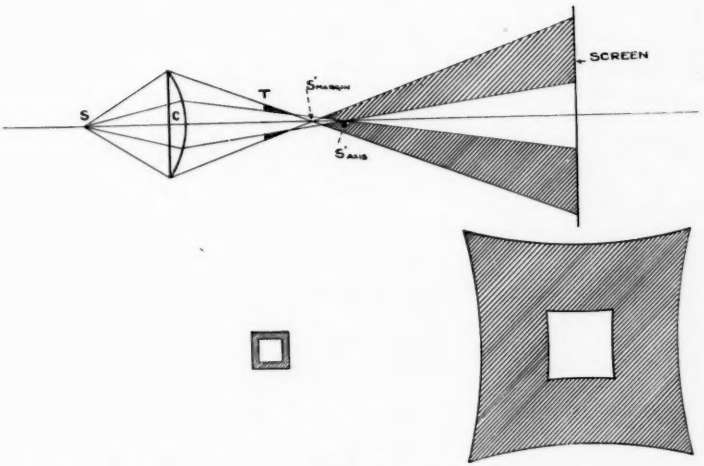


Fig. 3

Projection by means of a point shaped source and a spherically uncorrected condenser. The rays going through the margin of the condenser intersect the axis at S' margin nearer the lens and under a greater angle than those going through the lens near the axis which intersect the axis at S' axis. Parts nearer the margin of the object are imaged with higher magnification than those near the axis with the result that the picture on the screen shows cushion shaped distortion.

radiation than without it, we must be aware of the fact that the greatest part of the radiation from the source is lost as indicated in figure 2, because the radiation within the solid angle intercepted by the condenser is only a small portion of the total amount, which the source sends out in all directions. For optical reasons it is impossible to increase the diameter of the condenser very much beyond a size which takes in an angle of about 90 . The radiation within this angle can be increased considerably by placing a concave mirror behind the source so that its center of curvature lies in the source, figure 2. Assuming no loss of light by reflection on the mirror and by passing through the source the quantity of light reaching the condenser should be doubled by this expedient.

The conditions so far assumed do not exist in practice, because neither the condenser is optically perfect nor the source point shaped. We shall consider an

(a) Imperfect condenser in combination with a point shaped source, and understand by term imperfect nothing due to careless making of the condenser, but those imperfections in performance which are due to the nature of a simple lens system. These are spherical and chromatic aberrations. On account of the former, the different zones of the condenser will produce a series of images of the source; the nearer to the margin the zone, the nearer to the condenser the image produced by it, while with a spherically corrected condenser the rays from all the different zones of the condenser go through the same

point, or the hollow cones of light formed by the circumference of the zone as base line have the same apices. These cones have different apices with a spherically uncorrected condenser, the apices lying the nearer the condenser lens, the greater the diameter of the zone. The rays which pass through the margin of the condenser will, therefore, intersect the axis at 2: figure 3, under a greater angle than the corresponding rays in the arrangement with the perfect condenser. This increase of the angles will be small for rays passing near the center of the condenser and will become the greater the nearer to the margin of the lens the zone lies which produces the image. The effect is that the marginal parts of the field are imaged under a greater magnification than the center of the field. The image of a square object will show what is termed as cushion shaped distortion.

On account of the chromatic aberration, an uncorrected lens will produce images for the different colors composing the white light at the source at different distances from the condenser, the blue image

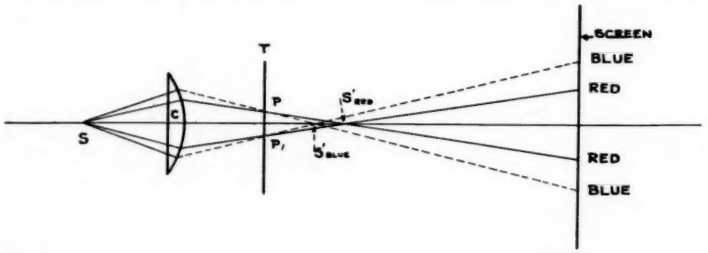


Fig. 4

Projection of a transparent point P of a stencil T by a chromatically not corrected condenser. The image of the source formed by the blue component of a white ray coming from the source and going through P lies nearer to the lens, at *S'* Blue than the image formed at *S'* Red by the red component of another white ray coming from the source. Therefore the blue image lies farther away from the center of the field, at "Blue," than the red image at "Red."

being nearest to the lens, the green, yellow, red, etc., lying at greater distances in the sequence given. For each color, therefore, an image will be produced in the same way as shown in the previous paragraph having spherical aberration and lying at different distances from the lens. We have to imagine the blue rays forming a cone of the same general shape as just shown, the green ones another one, a little more pointed, because the green image lies farther away from the lens, the red rays forming a still more pointed cone and so on. The precise shape of such a cone is further illustrated in figure ∞. A point of a stencil interposed in this multitude of cones will be projected by the red, green, blue and so on rays at different places on the screen because these differently colored rays intersect the optical axis at different places and under different angles. Figure 4 shows how a white ray drawn to pass through the margin of the lens, the blue component, and of another white ray passing nearer to the axis, the red component goes through the transferred point *P* of the stencil. Figure 5 shows the projection of a transparent point of the stencil. The red ray pro-

jects the point at R (red) and blue ray at B (blue). The green and yellow images will lie between the red and blue ones, and in place of a white image we will have a series of colored ones forming a spectrum. The length of this spectrum is a minimum when the stencil is located near the condenser and increases as the stencil moves towards the image of the source. The amount of this chromatic aberration depends only upon the power of the lens, its aperture and the magnification under which the source is imaged; in other words, if the location of the source and its image with reference to the lens and the angle a are given, the amount of chromatic aberration is determined. The thickness of the lenses has no influence upon it. Consider:

(b) The case of a perfect condenser and an extended light source. If the image of the light source is not point-shaped, the multitude of rays passing through a transparent point in the stencil causes a spot of light on the screen instead of a point, the size and shape of which is determined by the rays drawn from the object point through the differ-

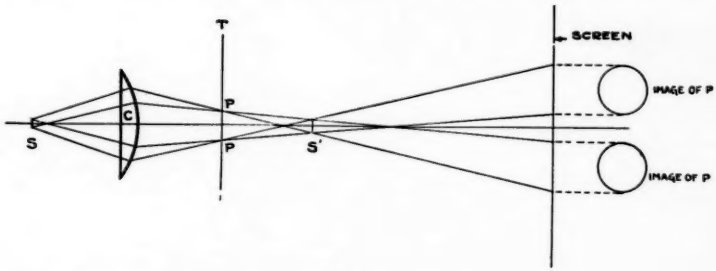


Fig. 5

Projection of a transparent point P of a stencil T with an optically perfect condenser and an extended source. The projection of the point on the screen is not point shaped, but a patch of light ("circle of confusion"), the size and shape of which depends largely upon the size and shape of the source.

ent points of the image of the source. The figure 6 shows how the rays forming the image of the source and crossing at the object point pass from the light source through different parts of the lens. The size of the spot of light on the screen which represents the projection of an object point will depend upon the size of the source, or its image, as well as upon the location of the object point between the condenser lens and image of source. Projection in this simple manner is possible only if the detail of the object is coarse in comparison with the size of the image of the source. For projection of detail of a minuteness beyond a certain limit, a projection lens will have to be applied as will be shown later. Consider:

(c) The usual case of an imperfect condenser in combination with an extended light source. Instead of having one image of the source, each zone of the condenser will produce an image of the source at a different place of the optical axis and for each color contained in the radiation from the source a different series of such images will be produced. The projection of the point takes place as described above

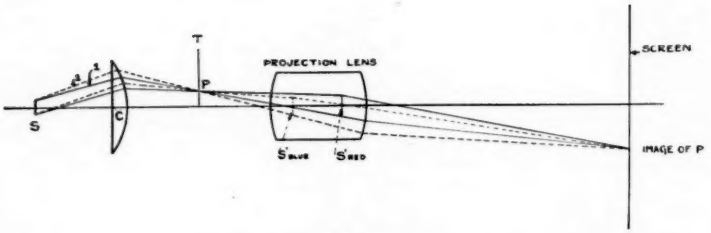


Fig. 6

Projection of a transparent point P of the stencil T by a projection lens in combination with an uncorrected condenser. Although the blue image of the source S' Blue and the red image S' Red are formed at different distances from the condenser C the projection lens reproduces a colorless image of P on the screen provided neither condenser nor projection lens are of sufficient size.

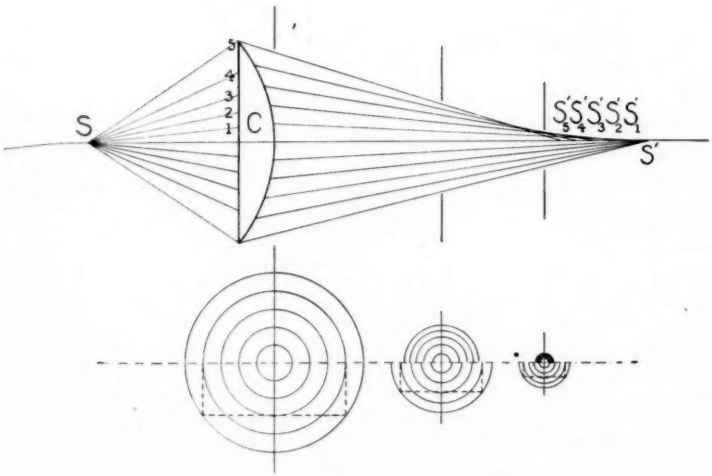


Fig. 7

Below the optical axis is shown the longitudinal section of a cone produced by a spherically corrected condenser, above the axis the section of a cone produced by a spherically not corrected condenser. While all zones of the spherically corrected condenser image the source S at S', the zones 1, 2, 3, 4, 5 of the uncorrected condenser produce images of the source at S_1' S_2', S_3', S_4' and S_5'. The three cross sections at different distances from the condenser allow a comparison of the distribution of light in these sections.

under (a and b) with the result that the light patch on the screen, the so-called circle of confusion, will have colored fringes, red towards, and blue away from the center of the field. The spherical aberration will add distortion to the image in the way explained above.

The patch of confused light which appears on the screen in place of the image of the object point caused by the size of the light source and by the chromatic aberration, can be converted into a true image of the object point by the interposition of a

(d) Projection Lens. Figure 6 shows the arrangement and also offers an explanation why in spite of the chromatic aberration of the condenser the image of the white object on the screen is white. We insert here that the image of the source must always fall in the aperture of the projection lens, which has to be large enough but need not be larger than necessary to pass all the radiation going from the condenser through the image of the source. The differently colored rays which intersect in the object point belong to white rays which fall upon different zones of the condenser lens. For instance, of the white ray from the source (1) a red component is refracted in the direction of the object point, while of a white ray (2) a blue component and of another white ray lying between (1) and (2) the green component leaves the condenser in the direction of an object point. This multitude of colored rays passing through the object point must, therefore, comprise all of the colors composing the light of the source and when gathered by the projecting lens and all brought to the same image point on the screen, form a white image of the object point. It is very evident also, that the image on the screen is white only if *all* the colored rays which may possibly go through the object point are united in the image on the screen. If, for instance, the diameter of the condensers were too small to pass the ray (2), the image would appear reddish yellow instead of white, because the blue is missing, or if the diameter of the projection lens were to be too small to let the red ray pass the image of the point would be bluish.

As long as we take care not to rob the pencil forming the image on the screen of any of its colored components, we shall have no difficulty on account of the chromatic aberration of the condenser. Of much greater influence is the effect of the spherical aberration. To obtain an even illumination of the screen, the section through the cone at the location of the stencil must be evenly illuminated. The cone of a perfect condenser offers sections with even distribution of light anywhere between the condenser lens and the image of the source—figure 7. There is a slight falling off of the illumination towards the margin for the same reason as stated at the beginning of this paper. A condenser which has spherical aberration will produce a cone in which the distribution of light is even only in sections near the condenser lens. The sections approaching the image of the source show a more and more increasing accumulation of light near the margin of the section because here the rays are more crowded together than in the central part of the field as may be seen in the figure. This is of no significance in lantern slide projection because the slide on account of its size is always located near the condenser, but very disturbing when, as in motion picture projection, the stencil is small and moved nearer to

the image of the source. If we place the stencil so that its diagonal is equal to the diameter of the cone, we shall have its corners in the marginal concentration of the light and, therefore, an uneven illumination of the stencil (see figure 7). To avoid this, the stencil has to be moved towards the condenser until its whole area lies in the evenly illuminated part of the cone. This means, of course, the loss of a very great percentage of light. The mere fact that a condenser has spherical aberration does not entail any loss of light if we are satisfied with an uneven illumination as long as the aperture of the projection lens is large enough to receive all the light passing through the image of the source. The sharpness of the image on the screen is not influenced by the spherical aberration of the condenser, if only the illuminating system is so centered that the image of the source, the spot, lies symmetrically to the center of the projection lens. If a slight decentration of the spot, without the spot getting outside of the aperture of the projection lens causes a deterioration of the image on the screen, the fault lies in the projection lens.

Another factor of influence upon the efficiency of a given combination of light source, condenser and projection lens is the size of the source and the location of the mat forming the border around the picture, the so-called aperture plate of the apparatus. The actual amount of light traveling from the condenser to the image of the source is embraced in a cone, the base of which is the condenser and the apex the image of the source. If the source is not point-shaped, the cone will be truncated.

We consider first a point-shaped source. If the stencil is of rectangular shape and its diagonal equal to the diameter of the light cone at the position of the stencil, the four segments of the illuminated source outside of the stencil do not contribute to the illumination. We shall refer to this in the following as diaphragm action (I). This is perfectly self-evident and there is no remedy for this loss unless we make the stencil circular. See figures of the half rectangles inscribed in the sections through the lower cone. Rectangular condensers have been suggested and are resuggested now and then, but instead of saving light, they cut out the unused light at a different plane of the optical system. They serve no purpose and are more expensive to make and to mount than the ordinary round condenser.

In case of a source of extended area the aperture plate does not only cut off these four segments, but also screens off parts of the condenser or of the light source in such a way that, while the radiation from the central parts of the source, which fills the condenser aperture, reaches the image of the source and, therefore, is utilized, the radiation from the extra axial points of the source, although it passes through the condenser, only partly reaches the image of the source and contributes to the illumination of the object point. We shall call this in the following diaphragm action (II.)

To simplify the drawings the light source and the aperture plate in the following are assumed to be circular. Figure 9 shows the path of the light rays from the center and from the two ends of the source as they pass through the condenser towards the image of the source s and s' are two conjugate points of the source and its image and the rays

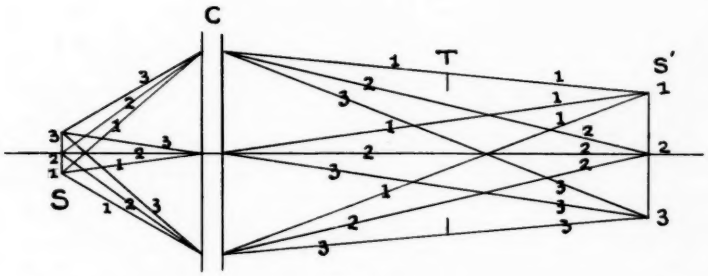


Fig. 9

Rays connecting the conjugate points 1, 2 and 3 of the source S and its image S'. From each of these points of the source a ray is drawn through center, upper and lower margin of the condenser C. The latter is represented here and in the two following diagrams by a pair of parallel lines.

connecting them are designated with the same figures (1), (2), (3).

Figure 10 illustrates how the ray from point 1 through the lower margin of the condenser does not reach the image point 1 and how the angle of useful radiation is smaller by the shaded portion than it would be were it not for the diaphragm action of the aperture plate.

Only the portions in the middle part of the source send forth cones which fill all the aperture of the condenser, while all the shaded parts of the pencils from points 1 and 3 are intercepted by the aperture plate as illustrated by the next drawing, figure 11.

We have to consider next the losses caused by

Absorption and reflection. The amount of light lost by absorption in a piece of glass depends upon the absorption coefficient of the material and on the thickness of the piece. The absorption coefficient varies from 1.3% per cm. for very clear glass to about 4% per cm. for very bad glass. The loss of light in a lens varies with the zones through which the light passes, depending on the different lengths of the path between the surfaces.

The loss by reflection depends upon the index of refraction of the

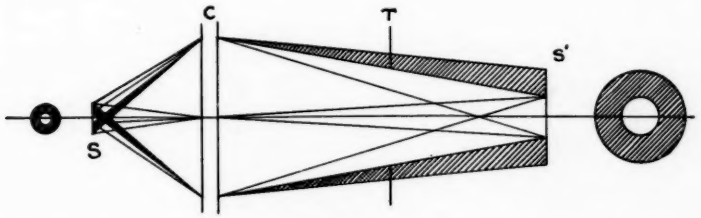


Fig. 10

The white circular areas at the right and left show the part of the image of the source imaged by the whole aperture of the condenser and the image of this part. The shaded anular zone around these circles represent the part of the radiation which is only partially by the condenser. The imperfect utilization of the area of the source is caused by the interposition of the aperture plate T.

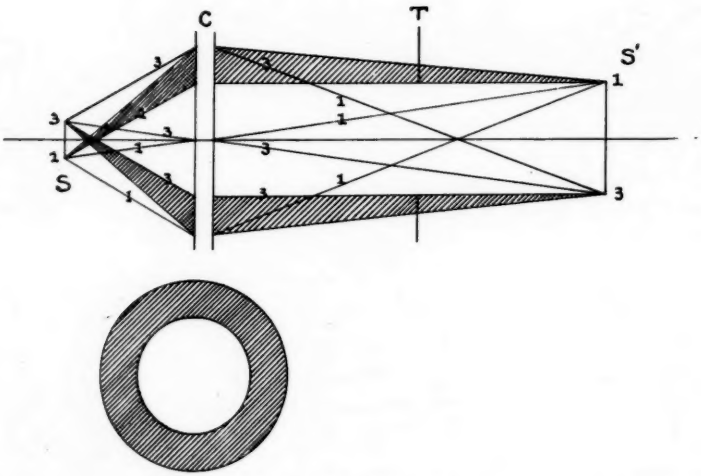


Fig. 11

Showing the part shaded of the solid angle of radiation from the ends of the source, which is diaphragmed by the aperture plate. The radiation from the ends of the source falling upon the shaded marginal zone of the condenser is not fully utilized on account of the diaphragm action (II) of the aperture plate.

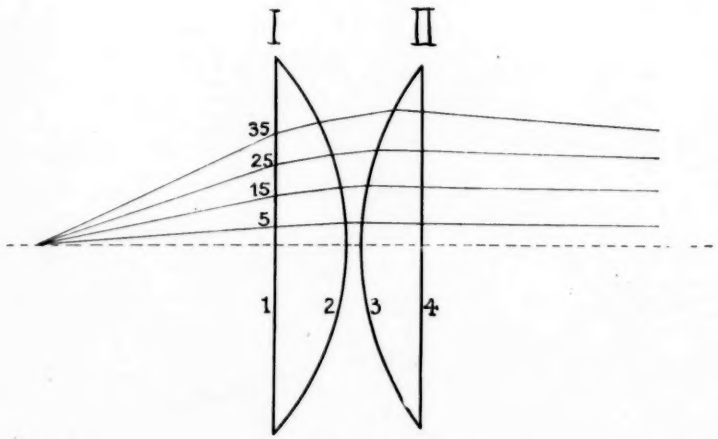


Fig. 12

The diaphragm shows the relative length of paths in an ordinary condenser through zones at a distance of 5, 15, 25 and 35 millimeters from the axis.

glass and upon the angle of incidence under which a ray strikes the surface. It increases, therefore, towards the margin of the condenser because the angles of incidence are greater there than nearer the center of the lens.

The following two tables show for 4 different zones of an ordinary M.P. condenser, the path lengths and the mean losses by absorption and refraction in these zones for the absorption coefficients 1.3% and 3.9% per cm., which are about the limit values for glasses available for this purpose. Figure 12 illustrates approximately the paths of the rays representing the middle of the zones through the condenser.

SPHERICAL DOUBLE CONDENSER

ABSORPTION COEFFICIENT 1.3% PER CM.

Distance of center of zone from opt. axis	Loss in % by reflection on surface				Loss in % by absorption and length of path in lens in (mm)		Sum of losses %	Loss in % in zone
	1	2	3	4	I (22.5)	II (19.4)		
5	4.4	4.1	3.9	3.6	2.7 (21.7)	2.1 (18.0)	20.8	1.3
15	4.4	4.1	3.9	3.6	2.6 (18.4)	1.9 (15.0)	20.5	3.9
25	4.4	4.2	4.0	3.7	2.3 (14.9)	1.6 (9.7)	20.2	6.3
35	4.8	4.5	4.2	4.0	1.9	1.1	20.5	9.0

Total Loss 20.5%

ABSORPTION COEFFICIENT 3.9% PER CM.

Distance of center of zone from opt. axis	Loss in % by reflection on surface				Loss in % by absorption and length of path in lens in (mm)		Sum of losses %	Loss in % in zone
	1	2	3	4	I (22.5)	II (19.4)		
5	4.2	3.8	3.7	3.3	8.2 (21.0)	5.9 (18.0)	29.3	1.8
15	4.4	3.8	3.7	3.3	7.7 (18.4)	5.5 (15.0)	28.4	5.3
25	4.4	3.9	3.8	3.5	6.9 (14.9)	4.7 (9.7)	27.2	8.5
35	4.8	4.3	4.1	3.7	5.5	3.2	25.6	11.2

Total Loss 26.8%

The same is done in the next two tables for a Fresnel lens, which is spherically corrected, has only 2 reflecting surfaces, less glass path, but higher angles of incidence in the outer zones. The average glass path is here the same for all zones and equals 10 mm.

FRESNEL LENS

ABSORPTION COEFFICIENT 1.3% PER CM.

Distance of center of zone from opt. axis	Loss in % by reflection on surface		Loss in % by absorption and length of path in lens in (mm)	Sum of losses %	Loss in % in zone
	1	2			
			(10.0)		
7.1	4.3	4.1	1.2	9.7	1.1
			(10.0)		
22.0	4.8	4.5	1.2	10.5	2.8
			(10.0)		
29.8	6.0	4.5	1.2	11.7	3.3
			(10.0)		
37.6	9.0	4.5	1.2	14.7	5.0

Total Loss 12.2%

ABSORPTION COEFFICIENT 3.9% PER CM.

Distance of center of zone from opt. axis	Loss in % by reflection on surface		Loss in % by absorption and length of path in lens in (mm)	Sum of losses %	Loss in % in zone
	1	2			
			(10.0)		
7.1	4.3	3.9	3.8	12.0	1.4
			(10.0)		
22.0	4.8	4.3	3.5	12.8	3.4
			(10.0)		
29.8	6.0	4.3	3.7	14.0	3.9
			(10.0)		
37.1	9.0	4.3	3.6	16.9	5.8

Total Loss 14.5%

Loss of light on a concave silvered glass mirror as used behind the light source is caused

(a) By the reflection of the in and out going ray on the outside surface, which amounts to about 8%,

(b) By reflection on the silver film, which varies considerably with the quality of silvering, 10% being an average figure, and

(c) By the absorption in the glass which amounts to from 1% to 4% for a mirror of 5 mm. thickness.

These figures add up to a total loss of about 20% on the mirror. If photometric measurements show in general a greater loss up to 50% in commercial mirrors, the reason may be found in most cases in the poor silvering and bad conditions of the surfaces.

In the case of a double condenser about 73% to 80% of the light contained in the angle $2u$ reaches the image of the source after having passed through the condenser. Of the 80% which in the best case is reflected by the spherical mirror, 20% to 27% are lost by passing the condenser so that the total amount which reaches the image of the source equals in the best case 80% + 64%, or 1.44 times the amount contained in the angle $2u$. If the higher figure for the loss in the condenser is taken, the total is reduced to 73% + 58% or 1.31.

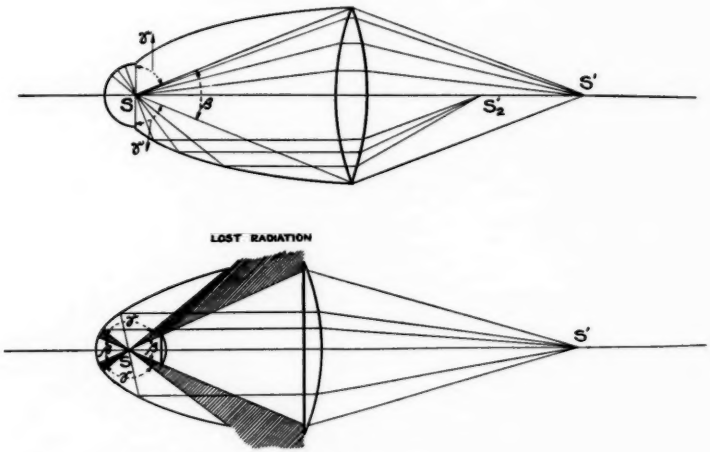


Fig. 13
Upper diagram: Petzval's Katadioptric Condenser.
Lower Diagram: Adaptation of an automobile headlight to a M.P. condenser

In case of a single condenser the corresponding figures will be 1.58 and 1.53.

The question may now be raised what, is the best result obtainable at the present state of the art and in which directions may improvements be made.

We found the following factors of influence upon the efficiency of the condenser system:

(1) Radiation from the source not intercepted by the optical system and, therefore, lost;
(2) Spherical aberration of the condenser;
(3) Chromatic aberration of the condenser;
(4) Diaphragm action (I) of the aperture plate on account of the rectangular shape of the opening;
(5) Diaphragm action (II) of the aperture plate on account of its location when the light source is not point-shaped;
(6) Absorption and reflection.

Of these the influence of (3) and (6) can be shortly dealt with. Chromatic aberration causes no loss of light in a properly designed system, while the loss by absorption and reflection which amounts to from 12% to 15% in single lens condensers and to 20% to 27% in doublets is absolutely unavoidable.

The loss due to the rectangular shape of the stencil, diaphragm action (I), cannot be avoided even by employing an optically perfect condenser and a point-shaped source and so there remain for consideration only the utilization of the radiation not intercepted by the condenser lens, the spherical aberration and the diaphragm action (II) of the aperture plate when the source is not point-shaped.

The utilization of the radiation not intercepted by the lens was attempted many years ago. About 1840, Prof. Petzval described a construction which I feel should be given the publicity it deserves, because it marks the limit of what can be accomplished in this direction. I was not able to refer to Petzval's original description and had to use a diagram in Hugo Schroeder's Elemente der Photographischen Optik. There is no interpretation of the diagram given and if the following should not do justice to the construction, I have to apologize to Prof. Petzval. In figure 13, s is the source placed in the center of curvature of a hemispherical mirror, which throws all the light radiating in the direction away from the condenser back into the source. At its equator the hemispherical mirror is joined coaxially by a paraboloid which collects the rays of the solid angle B and sends them in a direction nearly parallel to the optical axis towards the condenser lens which forms an image of the source at s'. All the light radiation within the solid angle B passes after reflection by the mirror through the condenser lens to the image point s' while the light radiating in the remaining solid angle d passes through the condenser lens directly, forming another image of the source at s'. The drawback of the construction lies in the technical difficulty of producing a perfect paraboloid and joining the two mirrors so that no shadow is cast within the cone and in the fact that two images of the source are produced. A paraboloid with badly-formed surface and also a decentration of the two mirrors are apt to cause uneven distribution of light in the cone even when the stencil is located near the lens. This apparatus may work well when used for lantern slide projection, but hardly for M.P. projection. Whether its efficiency is greatly superior to a good condenser made up of lenses in the usual way is somewhat doubtful if we consider the loss by reflection on the parabolic mirror and the fact that the greater part of the radiation is reflected by the hemisphere and then reflected by the parabolic mirror and, therefore, will suffer this loss twice.

Because of the similarity with Petzval's construction, we may mention here another one, which has been quite in vogue as an automobile headlight a few years ago and which is almost identical with the proposal made by Mr. Jenkins at the Rochester meeting in April, 1918. It contains (Fig. 13) a small condenser in whose focal point the source is placed and the usual arrangement of the concave mirror. The angle taken in by the condenser B and which is, at least, geometrically speaking, doubled by the mirror, amounts to about 50 degrees. This is thrown forward by the condenser in a beam of parallel rays by the condenser. A paraboloidal reflector is joined coaxially with the spherical mirror, so that its focal point coincides with the focal point of the lens and the center of curvature of the spherical mirror. This paraboloid intercepts the greater part of the radiation which is not used by the lens and spherical mirror and like the condenser lens, projects it forward in a parallel beam. By adding a condenser lens of the diameter of the reflector, an image can be formed of the source not far from the condenser and the combination be used for projection work. A similar effect can be produced by moving the source and the center of the spherical mirror outside of the paraboloid

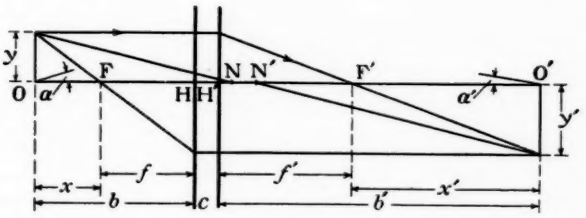


Fig. 1
An object y, imaged by an optical system represented by the principal points H and H', the nodel points N and N', and the focal points F and F'.

$$x.\,x' = f.\,f'$$

$$\frac{\mathrm{d}\,x'}{\mathrm{d}\,x} = -\frac{f.\,f'}{x^2} = -\frac{x'}{x} = \mathbf{X}$$

$$\frac{y'}{y} = \frac{f}{x} = \frac{x'}{f'} = \mathbf{Y}$$

$$\frac{\tan\alpha'}{\tan\alpha} = -\frac{x}{f'} = -\frac{f}{x'} = \mathbf{A}$$

$$y'\,n'\tan\alpha' = y\,n\tan\alpha$$

$$\mathbf{Y\,A} = \frac{n}{n'} = \frac{f}{f'}$$

$$\frac{\mathbf{X\,A}}{\mathbf{Y}} = 1$$

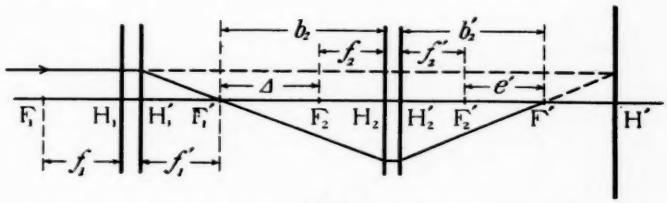


Fig. 2
A compound system composed of two elements represented by the principal points H_1, H_1' and H_2, H_2', and by the focal points F_1, F_1' and F_2, F_2', the distance F_1', F_2 being the optical interval Δ; object point at $-\infty$

$$f' = \frac{f_1'f_2}{\Delta} \qquad f = -\frac{f_1f_2'}{\Delta}$$

$$e' = -\frac{f_2.f_2'}{\Delta} \qquad e = \frac{f_1f_1'}{\Delta}$$

$f' = b'$ because $u = \infty$

and the condenser. The shape of the reflector should, however, be ellipsoidal in this case to prevent spherical aberration, which on account of the large angles of incidence near the margin of the reflector may reach enormous amounts. The combination produces one image of the source only when the focal points of the condenser and paraboloid coincide. Efficiency of this construction when used as motion picture condenser exists, probably, not even on paper. The spherical aberration can be partly avoided. Although inspection of Mr. Jenkins diagram shows uneven distribution of light, the effect of the great angle intercepted by the paraboloid is mostly offset by the loss of light on account of the very unfavorable angles under which the light is reflected, especially in the outer parts of the reflector. The centering of such a combination upon a common optical axis is not at all an easy matter, and the lack of centering will cause a one-sided, uneven distribution of light.

The spherical mirror behind the source is undoubtedly a valuable addition. It dates back to the early days of the magic lantern. I used it in 1908, in an apparatus for the projection of compass readings on ships in combination with an incandescent lamp. The filament in these lamps, which were made by the Westinghouse Electric Co., was of grid form and resembled a very steep "M" with rounded corners, over which the image superimposed itself like a "W", so that no screening of the image by the source took place, except in one point at each bend. The device was patented.

In 1917, the General Electric Co. secured a patent on a modification of this arrangement, limiting it to a parallel coil grid filament, "the area of the spaces between the coils" being equal to the "effective light emitting area of the grid coils," which is the form now so frequently used.

As mentioned above, the gain by the use of the mirror behind the source amounts to 50 to 75 per cent.

The influence of the spherical aberration can be offset by placing the stencil near the condenser, which is equivalent to a lantern slide arrangement in reduced size. While the condenser could be of the most common kind, it would be necessary to place the source nearer the condenser, than so far has been feasible at least with sources of considerable area. There would be no loss by diaphragm action (II) of the aperture plate. The condenser could, however, not be of the Fresnel type, otherwise the circles separating the zones would be projected into the image as shadows.

A condenser without spherical aberration has the advantage that the stencil may be placed anywhere in the cone, except in a condenser of the Fresnel type, where location near the condenser has to be avoided because of the shadows cast by the rings between the zones.

If the light source is point-shaped, no diaphragm action (II) by the aperture plate will occur wherever the latter may be placed. Diaphragm action (II) by the aperture plate will occur as soon as the light source has an extended area and as soon as the stencil is placed at a distance from the condenser.

A condenser without spherical correction, combined as usual with an extended source, is the least efficient combination, because of the

position of the stencil necessitated by the uneven illumination of the cone and the resulting diaphragm action (II) of the aperture plate.

Bearing in mind, that the concave mirror renders the same service in all cases and that the condenser which is composed of the smaller number of elements is preferable and that the stencil is located in the smallest section of the cone where it is evenly illuminated we sum up the different possibilities in the sequence of their efficiency.

(1) Small ordinary condenser, source not too large and near the condenser, stencil near the condenser, large projection lens.

Practical difficulties: the light source. Faults: none.

(2) Just as good: large spherically corrected condenser, point-shaped source at usual distance from condenser, stencil not near the condenser, small projection lens.

Practical difficulties: the light source. Faults: none.

(3) Spherically corrected condenser, extended light source at usual distance from condenser, stencil not near the condenser, large projection lens.

Practical difficulties: none. Faults: loss by diaphragm action (II) of the aperture plate.

(4) Large ordinary condenser, extended light source at usual distance from condenser, stencil not near condenser, large projection lens.

Practical difficulties: none. Faults: loss by spherical aberration and diaphragm action (II) of the aperture plate.

The nearer point-shaped the light source, the lower grade a projection lens may be used.

SPROCKET TEETH AND FILM PERFORATIONS AND THEIR RELATIONSHIP TO BETTER PROJECTION

By A. C. Roebuck

Among the further subjects that merit carefulattention by the Society of Motion Picture Engineers, there are probably none that present greater possibilities than those that may lead to the elimination of as much as is practicable of the unsteadiness or jumping of the picture on the screen.

It was prior to 1900, I believe, that means for the prevention of the side vibration of the film became a question of importance. The first effort toward the elimination of this objectionable feature was the use of a guide for the edges of the film, the guide for one edge being made flexible, but this plan was found to fall short of expectations and it never came into general use.

To undertake to guide the film accurately by the sprocket teeth was not possible at that time because of the wide variety in the sizes and forms of film perforations in use. Film perforators in the early days were mostly made under the direction of the maker of the films and there was apparently no effort made toward the standardization of the perforations. The length and width (especially the length) of the perforations and the distance between centers across the width of the film were different with each manufacturer, and it was found as late as 1906, I believe, that one manufacturer used at least five different forms of perforations. I believe the first perforations were rectangular in form with slightly rounded corners. Later the present type of perforation with circular ends was introduced, as I remember it, by Pathé Bros., of Paris, France, and this type of perforation has gradually grown in favor until it is now almost universally used.

The former perforations of varying lengths and widths and of varying distances between the centers of the perforations across the width of the film, placed the manufacturers of projecting machines at a great disadvantage, not only in being unable to use the sprocket teeth as a guide to prevent side vibration of the film, but also the wearing qualities of both the sprocket teeth and the film were reduced because of the teeth having to be made so much shorter than otherwise would have been possible.

Now that the general use of a standard film perforation is apparently a near future possibility, it seems it will be possible to use the teeth on one end of the sprocket wheel as a guide to prevent side shake by making them wide enough to fit the length of the perforation as is being done by at least one of the manufacturers of film printing machinery. To obtain the best results, this plan would require that the teeth must be properly formed, not only on the ends, but on their sides from base to point in order to give the film proper clearance as it engages and leaves the teeth.

Owing to the shrinkage in the film due to the elimination of moisture, especially while new, together with its expansion and contraction

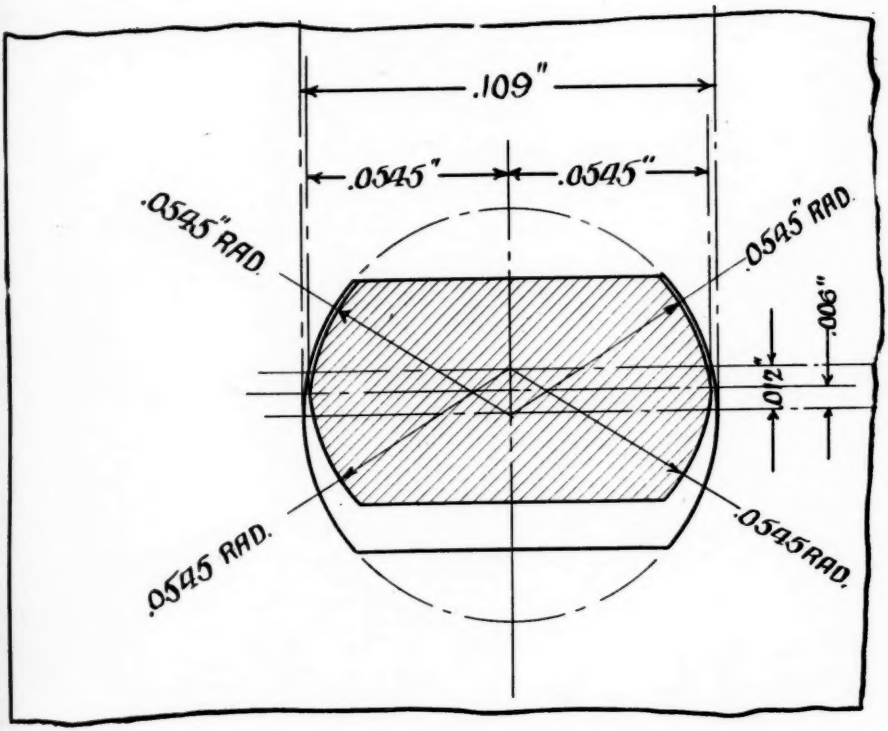


FIG. 1
Film perforations from Book of Standards.

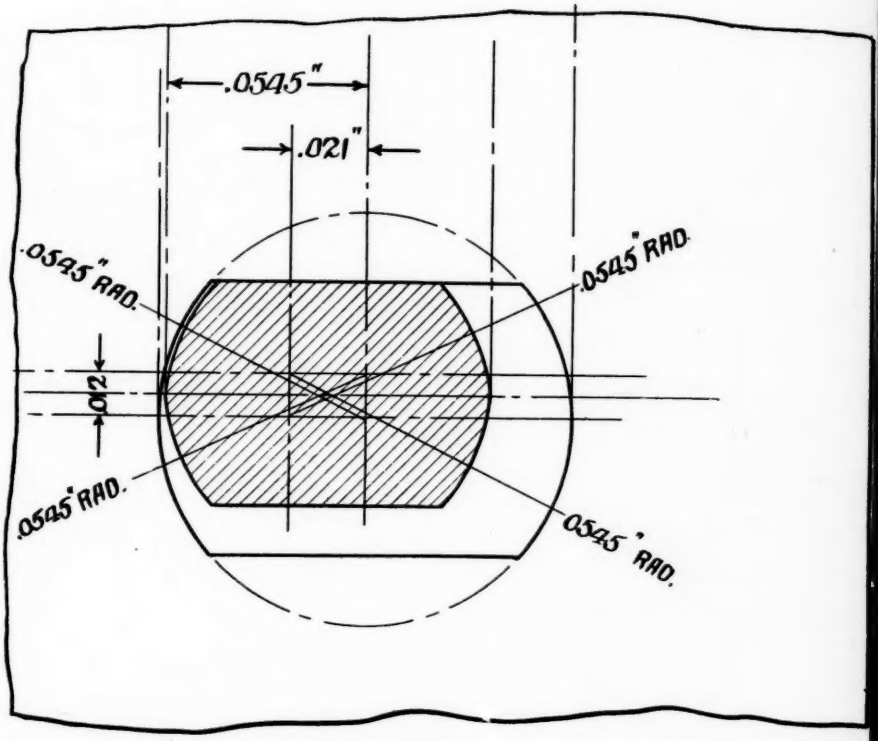


FIG. 1
Film perforations from Book of Standards.

from time to time due to atmospheric changes and moisture treatment it is not practicable to undertake to guide the film by having the teeth on both sides of the sprocket wheel the same length as the perforations in the film. Therefore, it seems necessary to make the teeth on one side of the sprocket wheel to fit closely the length of the film perforation and then shorten the tooth on the opposite side sufficiently to allow ample freedom for expansion and contraction in the width of the film.

At a recent meeting of the Society, the consideration that preceded the adoption of a standard for film perforation presented some complications because of the expected future relationship between the film perforation and the form and size of the sprocket tooth, and of finding a practical means for producing the film sprockets. It was the belief of some of those present that the use of a film perforation with circular ends would present complications in the forming of the sproc-

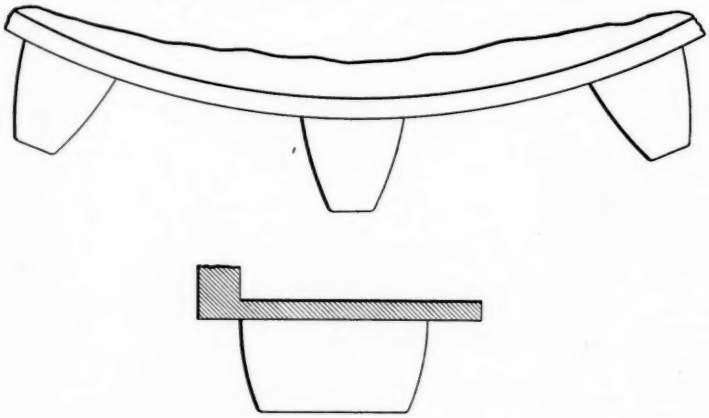


FIG. 2
Side and end view of sprocket tooth.

ket teeth to fit the perforations that might be so great the plan would not be practical, and that teeth made to fit a rectangular perforation with rounded corners would eliminate the complications in manufacturing, make it possible to grind both the ends and the sides of the sprocket teeth, thus correcting both the alignment and the spacing of the teeth, and would make it possible to secure the greatest degree of accuracy in the projection of the picture on the screen.

Mr. Bell of the Bell & Howell Company of Chicago, stated that for several years past they have been using on their film printers, sprocket wheels with teeth on one end made to fit the perforations in the film to prevent side movement, while the teeth on the other end of the sprocket wheel are made shorter. This plan has been possible with them because usually the film manufacturer who uses their goods adopts their equipment complete including film perforators, cameras,

printers, etc. Mr. Bell said they have been "forming" the teeth of the sprockets for their film printers, but that the method they are using for "forming" the teeth would probably not give satisfactory results in the production of a sprocket wheel of small diameter, such as is used for projection work. He said, however, they have given some thought to a method of "generating" the teeth that would be suitable for the production of sprocket teeth on a commercial basis with a sufficient degree of accuracy for practical purposes, and having in mind the present almost universal use of the film perforations with the circular ends, and the almost unsurmountable difficulties in the way of undertaking to get the manufacturers to change the form of tooth they are at pres-

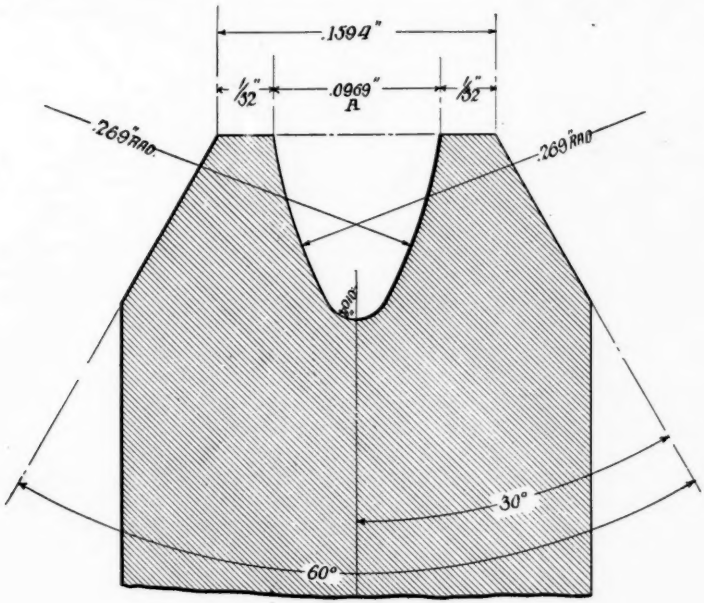


FIG. 3
Sectional plan view showing teeth and film perforations.

ent using, largely because of the great amount of expense involved in changing their machinery, cameras, etc., the Society thought best to adopt the film perforation with the circular ends with the understanding that in taking such action it would not necessarily be definite and could be changed at some future date in case developments should come about that would make a change advisable.

A diagram showing a strip of film with perforations, measurements, etc., adopted as a standard by the Society, appears in the latest issue of the book of standards, a copy of which is here reproduced.

Through the courtesy of Mr. Howell, I have secured blueprints

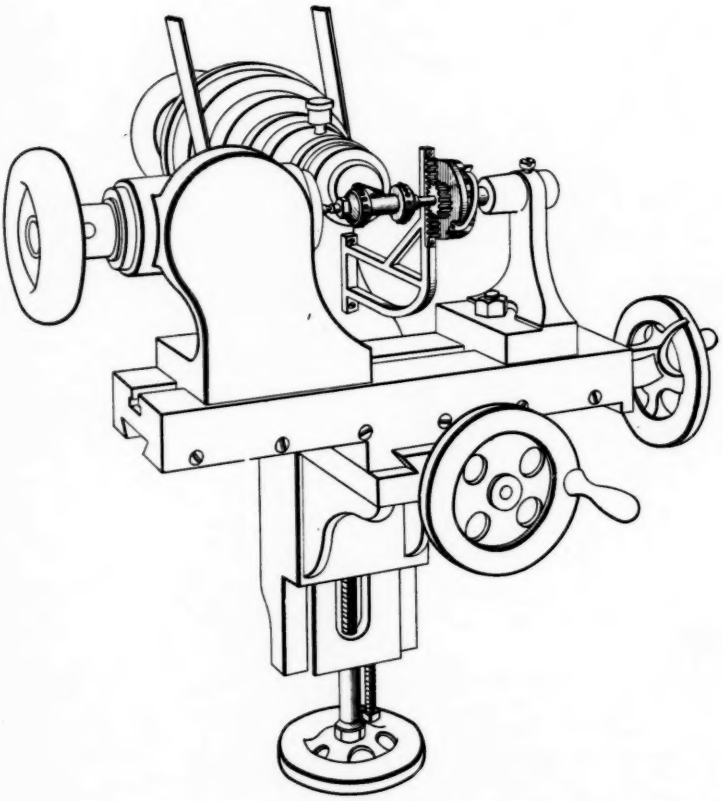


FIG. 5
Gear cutting device mounted on lathe for tooth generating operation.

showing the tooth with formed circular ends that is now being used in their film printers, and also showing the method used by them in forming the teeth to fit the perforations in the film. While satisfactory for forming the teeth on the large size sprocket used in their film printer, the process as previously stated would be objectionable for a sprocket wheel of approximately one inch in diameter as used in the projector, because at the base of the corners of the teeth an unfinished projection would remain, unless at the ends of the teeth the cutter would be advanced to the point where the flange of the wheel would be recessed to an extent that would be objectionable.

In making the teeth with ends formed by their present process, as shown in the accompanying drawings, a hollow mill or forming cutter is used. The mill operates through a bushing to center it, for the prevention of vibration and to make it possible to cut on only one side of the center. The sprocket wheel should be indexed for each tooth

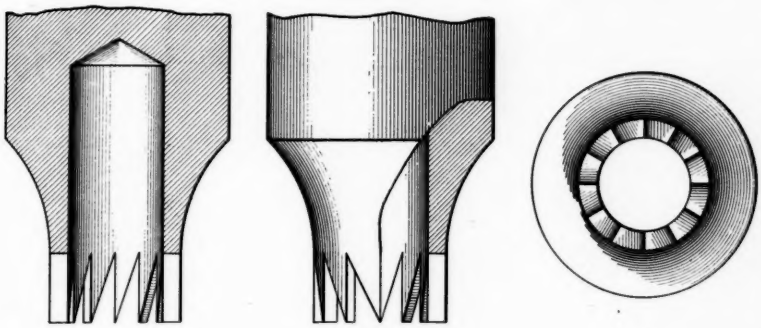


FIG. 4
Forming cutter with conical opening.

the same as in the regular operation of cutting the teeth on a gear cutter. The opening in the end of the cutter used for forming the teeth is made conical to fit the form of the tooth, as shown in Fig. 4.

As the width of the teeth are made less than the width of the perforation, the ends of the teeth are milled on one side of the center and then the sprocket is indexed .012 of an inch and the ends are milled on the other side of the center.

As a means for "generating" the teeth for use in a projecting machine, Mr. Howell has advanced the following theory, which as I understand it, has not been demonstrated to the point of determining definitely that it is practicable, but it seems to present encouraging possibilities. In this as in the preceding process, a hollow end mill type of forming cutter is used, the opening in the end of the former being cylindrical instead of conical as in the preceding form of cutter.

The hollow end mill for this process may be mounted in the spindle of a bench lathe, the cutting end being supported preferably in a bushing, while the sprocket wheel together with its index may be carried on a gear cutting attachment for the bench lathe. To perform the "gen-

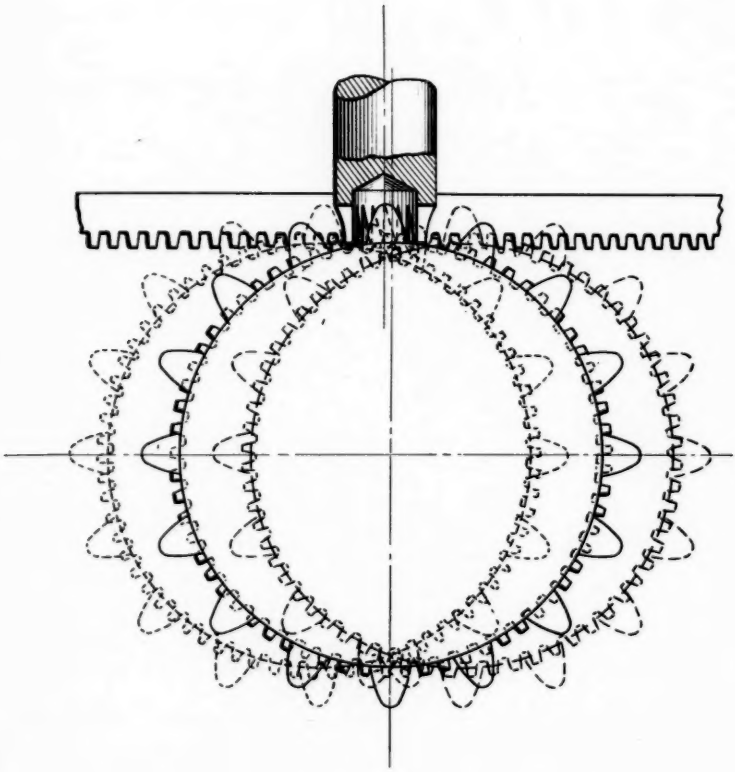


FIG. 7
Sprocket wheel in three positions with relation to the cutter.

erating" operation, it would be necessary to provide a rack and pinion movement, the rack being attached to the body or head of the lathe and the pinion loosely mounted on the spindle that carries the sprocket wheel. An index disc should be attached firmly on the shaft that carries the sprocket wheel, the index being used for the purpose of changing the relationship between the sprocket wheel and the pinion. The pitch diameter of this pinion should be equal to the diameter of the sprocket wheel plus one-half the thickness of the film. The rack should be placed on the same side of the gear as the end mill for forming the teeth. Thus, the pitch line of the rack and gear would be the same as the pitch line of the film and the sprocket teeth.

It would be necessary to eliminate from the rack and pinion connection all possibility of lost motion and for this purpose it is probable that a double rack, adjustable endwise, such as is used on profiling machines, would be desirable for the purpose.

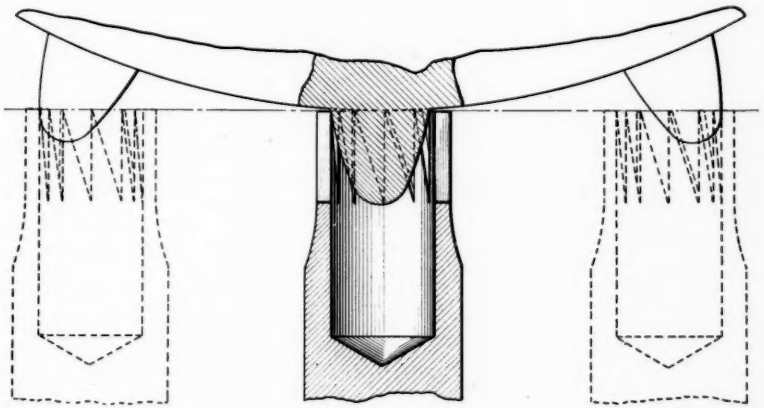


FIG. 8

Enlarged view of tooth and cutter only, with tooth in section, and on a line near the end of the tooth where it comes in contact with the matter.

It will be seen by the accompanying sketch that when the carrier of the sprocket tooth is moved up or down the connection of the gear with the rack will give the sprocket a rolling movement, and if the sprocket wheel and tooth are positioned so that when the center of the sprocket shaft reaches a point on a line horizontal with the center of the forming cutter, and the center of the sprocket tooth will at that time also be in the same line, the rolling motion given to the sprocket tooth as it enters and leaves the opening in the cutter will apparently form the tooth in accordance with the requirements.

It has been my opinion, and I believe it is generally agreed, that the best results can be obtained by the use of rectangular perforations because in that case after rounding the corners of the teeth with a forming cutter, the sides and ends of the teeth could be ground. This too

would apparently make it practicable to harden the sprocket wheels and then correct the distortion from hardening by grinding, whereas it would seem that the method of generating the teeth with a forming cutter as previously described, permits the making of soft sprockets only, the form of the teeth of which quickly change through wear. It may be that some method might be devised for the use of a forming grinder having a small hollow grinding wheel, such as a lap of tough metal and charged with abrasive material to revolve around the tooth as the sprocket wheel is fed past the grinding attachment, but it is probable such a plan would not be practical.

In presenting this method as a means of generating the sprocket teeth, I wish it understood that I am not in a position to vouch for it in that it is a theory that has not been proven. I have endeavored to present it as nearly as possible as it was explained to me, having myself added the suggestion for the use of the double rack as a means of eliminating the lost motion. It would seem, however, that it presents promising possibilities as the only practical method whereby we may expect under present conditions to be able to guide the film to prevent side movement, and it is to be hoped that it may lead to practical results and ultimately result in the adoption of a standard that will add substantially to further accuracy and efficiency in film projection.

Discussion

Following the paper, the chairman opened the discussion by emphasizing the necessity of the grinding operation. He also brought out, that the grinding operation might be limited to simply bevelling off the corners. Mr. Roebuck objected that this would leave a corner which would be dangerous to the film.

Along the line of grinding, Mr. Mayer suggested that the question of suitable grinding material could be easily handled, citing the Chemical Exposition at New York where a number of various moulded abrasive materials were shown.

Mr. Roebuck brought up another possibility, that of using a hollow grinding tool instead of a hollow mill, providing proper feeding could be arranged.

Here the discussion digressed to the question of the relative motion of the sprocket and cutter, Messrs. Mayer, Roebuck, Cook and the chairman taking part.

Mr. Roebuck brought back the discussion to the question of feeding a grinding tool to take care of the wear of the abrasive and suggested a method. Mr. Richardson objected that this would not be accurate, at least from the standpoint of production. Mr. Roebuck said that it would be practical from the mechanical point of view. Mr. Richardson added that it would be all right if the grinding proposition were taken care of as an additional operation, but doubted the accuracy if the sprocket were generated by grinding. Short discussion on the accuracy question by Mr. Richardson and Mr. Roebuck followed.

Mr. Victor offered a suggestion of generating by the use of a hollow tapered grinder or cutter and rocking the sprocket. This would approximate the generated tooth and would be accurate enough for practical purposes. Mr. St. John approved Mr. Victor's suggestion.

Mr. De Vry objected that the cutter would soon deform. Mr. Victor took care of his objection.

Mr. Roebuck concluded the discussion by emphasizing the practicability of accuracy with low cost. He told of an automatic machine which he saw at the Chicago World's Fair, which made the barrel arbor in a watch movement. He illustrated by a sketch on the blackboard what the arbor is, and the fact that it must be accurate enough to be interchangeable within all watch movements of that make. This machine was doing the several operations necessary automatically and yet with sufficient accuracy, that the finished pieces cost the trade only about 30 cents apiece.

FUNDAMENTALS OF ILLUMINATION IN MOTION PICTURE PROJECTION

By R. P. Burrows

A paper presented before this Society entitled "Light Intensities for Motion Picture Projection" called attention to the many factors which enter into the determination of a suitable light intensity for the motion picture screen. Since this paper was presented, experience in the motion picture industry has shown the necessity of bringing to the attention of those interested in the development of the industry, through motion picture journals, conventions such as this, and through personal contact, a conception of the fundamentals of illumination measurement.

In reviewing the Transactions of this Society and the handbooks on projection, it is found that serious attention has not been given to light measurement. It seems desirable at this time to present material in a simple form which can be used as a basis for educational work which it seems to me this Society should do to help eliminate the guesswork from motion picture projection.

Comparisons of the candlepower of arc lamps when employing right angle carbons, inclined carbons, various sizes of carbons, various ampere strengths, etc., etc., are interesting and very instructive from certain standpoints, but the one result in which the projectionist is chiefly interested is the brightness of the picture to the eye of the observer. It is readily apparent that because of differences in the optical systems, differences in the reflection characteristics of various screens, differences in the fineness of adjustment, etc., two sources of very different candlepower might give equal results so far as the spectators are concerned.

To obtain a true comparison of the results obtained with different systems, it is necessary to use units of measurement which are not familiar to the motion picture industry. Just as we once had to learn that there is a unit called the yard which is used to measure length, that the gallon is a unit used to measure quantity and contains 231 cubic inches, so in dealing with screen intensities certain fundamental units must be studied before measurements can be made and before definite relations of cause and effect can be comprehended or expressed. Basic definitions have a very academic and sometimes a very technical sound, although the units themselves, once their definitions have been assimilated, and not merely learned by rote, are comparatively simple. The definitions need not be committed to memory but should be thoroughly digested so that the distinction between the different units will be grasped and a working knowledge of what each stands for and the quantity it represents will be obtained. Very few electrical engineers or electricians could offhand give a basic definition of the ampere*, although they might all know that it is a measure of

* The ampere is defined technically as the practical equivalent of the unvarying current which, when passed through a solution of nitrate of silver in water, in accordance with standard specifications, deposits silver at the rate of 0.001118 gram per second.

rate of flow of electric current and have a practical conception of the magnitude of the unit. In dealing with illumination measurements it is more practical to have a conception of the quantity of light represented by one lumen, than it is to be able to tell precisely what a lumen is. Obviously, it is of advantage to standardize certain units so that relations of magnitude can be expressed and understood with precision, although the value we arbitrarily assign as a standard is of little importance except from this standpoint.

The Candle.

A generation or two ago, when new light sources began to supersede the candle, it was most natural that the illuminating power of these new sources should be expressed in terms of the candle familiar to all. It is probable that the very first comparisons of two light sources were made by setting up the two lamps in the line of vision and gauging them by means of the eye, the most natural direction in which to look at the sources being the horizontal.

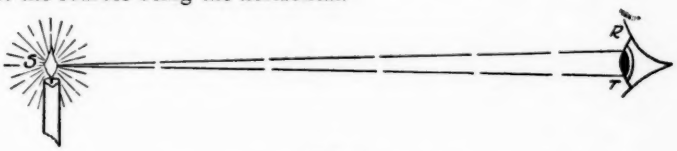


Fig. 1
Only a slender cone of light reaches the eye

A glance at Fig. 1 shows that the eye (an extremely fallible instrument of light measurement at its best) is capable of measuring only a very slender cone of light at one time; in fact, if the eye is an appreciable distance from the source, the cone RST becomes virtually a single line.

While there are an infinite number of directions from which the eye might look at the source, the light-giving power in a horizontal direction was made the basis of comparisons, and the strength of the light in this direction from a candle made according to certain definite specifications, was arbitrarily chosen as the unit of intensity and called a candle. The newer illuminants appearing on the scene were rated according to their strength in this same direction and were stated to give so many candles. This rating of an illuminant is made by means of an instrument known as a photometer, a description of which will follow later. One essential point to remember in this connection is that the candle-power of a lighting unit represents the intensity in one direction only. In practice it has been customary for years to rotate the illuminant about a vertical axis while the candle-power was being determined and the result was known as the mean or average horizontal candle-power but even this determination gives an average value of the intensity in the horizontal direction only.

To carry our conception of candle-power a little further, let us assume three conditions.

In the first case (Fig. 2A) we have on the left a standard candle and on the right a photometer pointed toward the candle. From what has

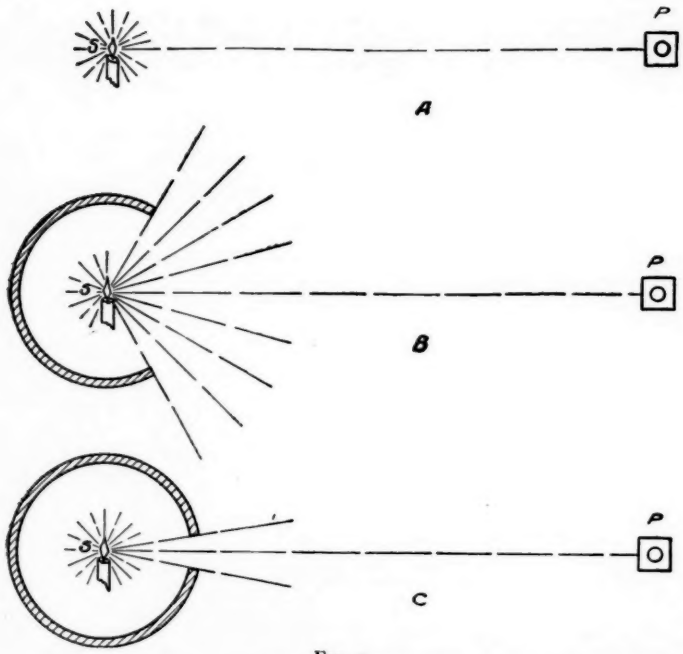


FIG. 2
The candle power in the direction of the Photometer is not changed by partially surrounding the light source with a non-reflecting surface.

already been stated, it is obvious that when the photometer is balanced it will indicate an intensity of 1 candle.

In the second case, (Fig. 2B) we have used a sphere with a much smaller opening and are, therefore, wasting still more of the light, but even in this case our photometer will indicate an intensity of 1 candle. In fact, our reading will be 1 candle regardless of the size of the opening, that is, regardless of the quantity of light we allow to be emitted, provided the direct rays from the candle to the photometer are not obstructed. This leads us to the important conclusion that the candle-power of a source gives no indication of the total quantity of light emitted by that source. Candle-power, we may say, is analogous to a measurement of the depth of a pool of water at a certain point on its surface—a measurement which is useful for certain purposes, but in itself gives no indication of the quantity of water in the pool.

The first fundamental concept we have to deal with in illumination, then, is candle-power, which is the measure of strength of a source to produce illumination in a given direction, and the power in a horizontal direction of a candle made according to certain specifications and burning under certain conditions has been arbitrarily chosen as the unit for measuring this strength.

Closely related to candle-power is mean spherical candle-power. The mean spherical candle-power of a lamp is simply the average of all the candle-powers in all directions about that lamp.

The Lumen.

We have seen that candle-power alone gives no indication of quantity* of light. It is necessary, therefore, for us to develop a unit whereby we can measure the quantity of total flux of light emitted by a source.

For this purpose let us assume a source giving one candle in every direction, and that this source is placed at the center of a sphere painted black on the inside and having a radius of, say, 1 foot,

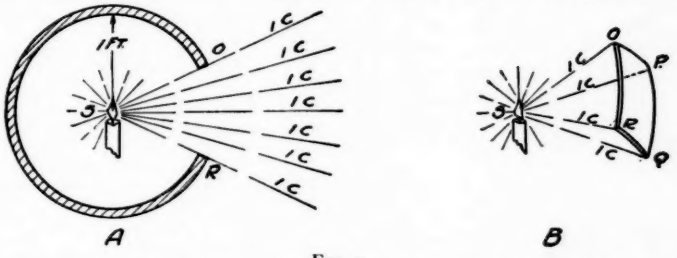


Fig. 3

Opening *OR* has area of 1 square foot and emits 1 lumen; B One lumen falls on surface *O P Q R*

(Sketch A, Fig. 3) *OR* represents an opening in the sphere through which some of the light may escape. The quantity of light allowed to escape may be varied by varying the size of the opening, with the candle-power of the source and the radius of the sphere remaining fixed; if we decide on some definite size of opening at *OR* we shall have a definite quantity of light which we can use as our unit for measuring quantity. The simplest area or unit to assume for *OR* is 1 square foot, and if we do make this opening of an area of 1 square foot, the amount of light that escapes is considered to be the unit of quantity, and is called a lumen. †Thus we have established a permanent unit for the measurement of quantity of light; the mathematical relations used to fix it serve only the same purpose as two scratches on a platinum-iridium bar in the International Bureau of Weights and Measures, the distance bweteen which at a definite temperature is called a meter.

If the area of *OR* is made ¼ square foot, the light escaping will amount to ¼ lumen; if the area of *OR* is doubled, the light escaping will be 2 lumens. On the other hand, if we have a uniform source of 2 candles instead of 1, 2 lumens will be emitted through an opening of 1

* Quantity is here used in the sense that it indicates only a summation of flux as throughout a given solid angle about the source, and over a given area illuminated to some average value. Quantity in a more precise sense is a summation over a period of time and is measured in lumen-hours.

† We could choose a sphere of any radius we cared to, as long as we kept the proportions the same by making the size of the opening such that its area would be equal to the square of the radius. The quantity would still be one lumen.

square foot in this particular sphere. We know by arithmetic that the total surface of the sphere having a radius of 1 foot is 12.57 square feet. In other words, removing the sphere entirely, we would have the equivalent of 12.57 openings the size of *OR;* that is, if the candle gives 1 candle in every direction, with the sphere removed it would give 12.57 lumens. This means that if we know the mean spherical candle-power of a source by multiplying this value by 12.57 we obtain the number of lumens emitted by that source. A lumen may also be defined as being equivalent to the quantity of light intercepted by a surface of 1 square foot every point of which is at a distance of 1 foot from a source of 1 candle. (Fig. 3, Sketch B).

While the foregoing definitions establish definitely the quantity of light that we use as our basic unit, it must be remembered that a lumen, in order to be a lumen, need not necessarily conform with these specifications if the quantity of light represented is equivalent to that prescribed by the definition. A bushel might be defined as the quantity of any commodity contained in a cylindrical measure having a diameter of 13½″ and a height of 8″; however, a bushel of potatoes spread out in the field is just as much a bushel as though the shape of the pile conformed in every respect to the dimensions just mentioned.

A conception of the relations just discussed may be obtained from the following simple analogy: Suppose that we have a pool of water of unknown depth, whose area has been found to be 5000 square inches, and it is desired to obtain a measurement of the quantity of water in the pool. At first thought, one might be tempted to measure the depth at some point by means of a yardstick. If, for example, the depth at this point were found to be 6 inches, he might say that the pool contained 6 inches of water. Obviously, such a measurement would be practically useless. A measurement of this sort corresponds to the measurement of the quantity of light given off by an illuminant as determined by its candle-power in a single direction. On second thought, the investigator might make determinations of depth at regular intervals along a straight line through the center of the pool from edge to edge and find the average depth along this line to be, say, 4 inches. To say that the pool contains 4 inches of water would hardly be more conclusive than the first determination. Such a measurement would correspond to the mean horizontal candle-power of a light source. If the surface of the pool were divided into a large number of equal squares and measurements of depth made at the center of each square, the average depth thus found would give a definite idea of the quantity of the water in the pool since the surface area is already known. This determination corresponds to mean spherical candle-power. Now, if the average depth of the pool as just determined, is, say, 4½ inches, the quantity of water in the pool is 4½ times 5,000 or 22,500 cubic inches. To say that the pool contains 22,500 cubic inches of water is definite and positive, and this measurement corresponds to the number of lumens given off by a light source. The average depth of the pool corresponds in this analogy to the average intensity of the light source in all directions and the area of the pool corresponds to the area of the imaginary sphere about the light source.

It might be said that the above method would be a very awkward

one to employ in determining how much water there is in the pool. A more practical method would be to pump the water into some measuring vessel, as, a barrel graduated in gallons. As a matter of fact, measuring the total lumens emitted by a light source is performed in a manner analogous to the method just referred to. The mean spherical candle-power or the lumen output of an illuminant may be determined at one reading by means of an instrument known as a sphere photometer.

The Foot-Candle.

Light is a cause and illumination the effect or result. Both the lumen and the candle are used to measure the cause, these units applying to the light source itself and not to the point where the light is utilized. To measure the illumination on a newspaper, desk or on a motion picture screen, we employ a unit called the foot-candle. A foot-candle represents an intensity of illumination equal to that produced at a point on a plane which is 1 foot distant from a source of 1 candle and which is perpendicular to the light rays at that point.

In Fig. 4, if the source *S* gives an intensity of 1 candle along the line *SA* and if *A* is 1 foot distant from the source, the intensity of illumina-

Fig. 5
The Illumination is less on A′B′ than on AB (see footnote)

tion on the plane *CD* at the point *A* is one foot-candle.* The intensity of illumination, measured in foot-candles, is the unit of measurement most intimately associated with our everyday use of light, and a measurement which the eye either consciously or unconsciously is making whenever the faculty of vision is being employed, for the number of foot-candles we have on the screen, other things being equal, determines directly whether or not there is sufficient light.

A working idea of a foot-candle of illumination can be obtained by considering the intensity on a newspaper being read by the light of a candle, the paper being held approximately one foot away from the candle. The foot-candle is a unit applying to a point on a surface; by averaging the foot-candles at a number of points on a plane, we get the average intensity of illumination on that plane.

Care should be taken to avoid confusing the intensity of illumination on a surface as indicated by the foot-candles with the appearance

* If instead of being perpendicular to the beam, the plane *AB* is tilted at an angle, as shown in Fig. 5, it will be seen that the light of this beam is spread over a greater area than if the plane is perpendicular, so that the intensity of illumination on the plane is less in proportion to the ratio of the length of *AB* to the length of *A′B′*, or to the cosine of the angle between a perpendicular to the *A′B′* and the axis of the beam, which is the angle *X*. If, with the plane in the position *AB* the illumination is 1 foot-candle and the cosine of the angle *X* is 0.7, the average illumination on the plane in position *A′B′* will be only 0.7 of a foot-candle.

as regards brightness of the surface. For example, a dusty or dirty screen lighted to an intensity of five foot-candles will not appear so bright as a white one, for a greater proportion of the light falling upon the screen is absorbed and lost. The brightness of an object depends upon both the intensity of illumination on it and the percentage of light that it reflects.

Having defined the foot-candle as a unit of intensity of illumination, we are naturally interested in seeing how the intensity of illumination varies as the candle-power of the source varies, and also as the area over which a given beam is spread varies. It is obvious that if, in Fig. 4, instead of an intensity of one candle along the line *SA*, we have an intensity of two candles, the illumination at '*A*' would be twice as great, and that if we have an intensity of five candles the illumination at '*A*' will be five times as great. Now, if we consider a source of one candle as shown in Fig. 6, we know that the intensity of illumination on '*A*' which is one foot distant is one foot-candle. If, however, we remove the plane '*A*' and allow the same beam of light that formerly was intercepted by '*A*' to pass on to the plane '*B*,' two feet away, we find as shown in the diagram that this same beam of light would have to cover four times the area of '*A*'; and, inasmuch as we cannot get something for nothing, we would find that the average intensity on '*B*,' two feet away, would be one-fourth as high as that on '*A*' 1 foot,

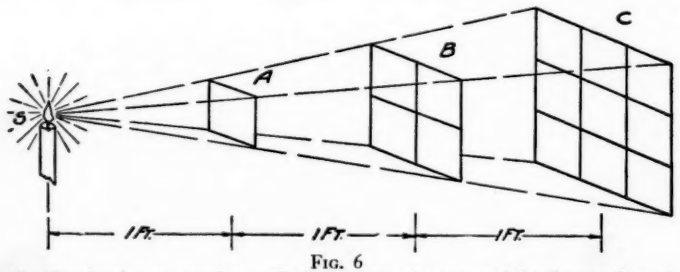


FIG. 6

The Illumination on a surface varies inversely as the square of the distance from the source to the surface.

away, or one-fourth of a foot-candle. In the same way, if '*B*' also is removed and the same beam allowed to fall upon plane '*C*,' three feet away from the source, it will be spread over an area nine times as great as '*A*,' and so on; at a distance of five feet we would have only one-twenty-fifth of a foot-candle. From this we deduce that the intensity of illumination falls off not in proportion to the distance ,but in proportion to the square of the distance. This relation is commonly known as the inverse square law.

IMPORTANT RELATION BETWEEN FOOT-CANDLE AND LUMEN.

If we refer back to Fig. 3B, we see that the surface *OPQR* is illuminated at every point to an intensity of one foot-candle. We also know by definition that the quantity of light falling on the plane *OPRQ* is one lumen. This gives us the important law that if one lumen is so

utilized that all of the light is spread over a surface of one square foot, that surface will be lighted to an average intensity of one foot-candle. This relation is an important one for once the number of square feet to be lighted and the intensity of illumination which it is desired to provide are known, it is a simple matter to find how many lumens must be supplied to the surface. If, for example, it is desired to illuminate a surface of 100 square feet to an average intensity of five foot-candles, 500 lumens must be utilized.

Photometry

Photometry is a specialized branch of the science of illumination which in itself may be made the subject of an extended study. The man doing field work in illumination has no need for an intimate knowledge of all the details that enter into this branch of the art. In the following discussion, photometers are treated in a broad, general way and for more detailed description of the instruments, the reader is referred to standard works on the subject of illumination and photometry.

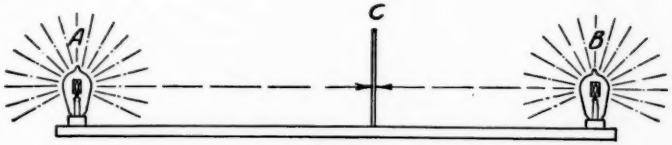


Fig. 7
Essential Parts of Horizontal Photometer

A sketch of the most simple type of photometer is given in Fig. 7. The essential part of this photometer is a vertical paper screen between the lamps to be compared, at the center of which is a grease spot. When the illumination on one side of the screen is greater than that on the other, the spot will on this side, appear darker and on the other side lighter than the surrounding paper. By sliding the screen back and forth on the bar, a position can be found where the outlines of the spot will vanish and the spot itself will disappear. When this condition obtains, the illuminations on both sides of the screen are the same.

In order that both sides of the screen may be seen simultaneously, mirrors are mounted obliquely behind the screen. In Fig. 8, Case A, it will be noted that the spot as viewed in the left-hand mirror is darker than its surroundings and as viewed in the right-hand mirror is lighter than its surroundings, which indicates that the left-hand side of the screen is illuminated to a higher intensity than the right. In Case B of the same figure, it will be noted that the conditions are reversed; therefore, in this case the illumination on the right side of the screen is greater than that on the left. Somewhere between these two positions is a position at which the spot will cease to be visible, as shown in Case C of Fig. 8.

From what has been said above, the intensities of illumination on both sides of the screen in Case C are equal. Now, since we have a re-

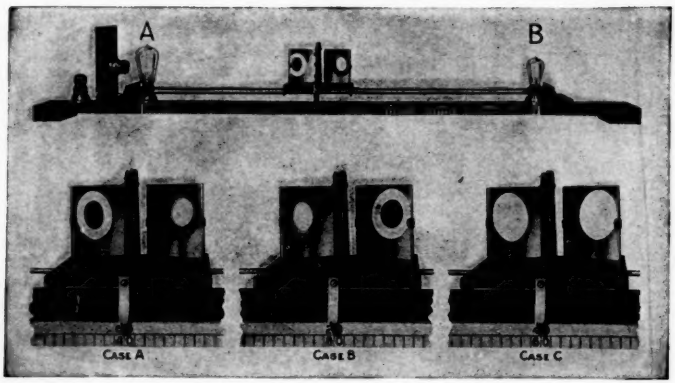


FIG. 8
PHOTOMETER AND SCREENS
Case A—Screen at left of balance point
Case B—Screen at right of balance point
Case C—Screen at balance point

lation between the intensities of illumination that the two lamps being compared are able to produce, we can reason back as to the relation between the candle-powers given, respectively, by lamps *A* and *B* (see Fig. 8). The scale of the photometer shows us that at a distance of 60 inches the lamp *A* produces an illumination equal to that which the lamp *B* can produce at a distance of 40 inches. At first thought we might say that *A* must give $\frac{3}{2}$ as great a candle-power as *B*, but recalling the inverse square law referred to on page 14, which states that the intensity of illumination varies inversely as the square of the distance, or what is the same thing, that the candle-power necessary to produce a given illumination varies as the square of the distance from the source of the plane, we see that the ratio of the candle-power of *A* to that of *B* instead of being 3 to 2 is 3^2 to 2^2 or 9 to 4. The horizontal candle-power of *A*, therefore, is 2¼ times that of *B*. If *B* is a lamp of some known candle-power, the candle-power of *A* is determined by multiplying the candle-power of *B* by 2¼. The general rule, then is that the candle-power of two lamps on a photometer are to each other as the square of the distances from each to the screen are to each other. For accurate photometry, the grease spot screen is no longer in use, but the newer and more accurate photometers are the same in principle.

The simple bar photometer measures candle-power in one direction only. If the lamp being measured is rotated about its vertical axis, its mean horizontal candle-power is obtained. In like manner, if the vertical axis of the lamp being measured is tipped and the lamp rotated on this axis, the average candle-power at any angle can be determined.

An instrument called the foot-candle meter as mentioned last year, has been designed to measure foot-candle intensities quickly and with

a fair degree of accuracy. It is very simple in operation, so light that it can be easily carried about, and so small that readings can be taken in very restricted spaces. The instrument is shown in Fig. 9. In operation, it is placed upon or adjacent to the surface on which a measurement of the foot-candle intensity is desired. A lamp within the box illuminates the under side of the photometric screen to a much higher intensity at one end than at the other. The illumination which it is desired to measure is, of course, practically uniform over the entire scale. Closely spaced translucent dots, which serve the same purpose as the grease spot in the simple bar photometer, line the scale from end to end. If the illumination on the scale from the outside falls within the measuring limits of the meter (0.5—25 foot-candles) the spots will appear brighter at one end of the scale than at the other, and at the point where the spots are neither brighter nor darker than the white paper scale the illuminations from within and from without are equal. The scale is accurately calibrated with the lamp within the

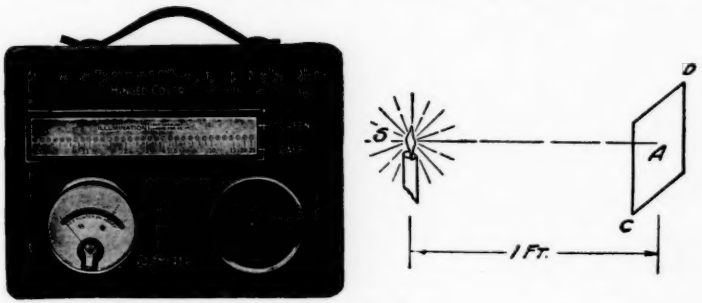


FIG. 9
Foot Candle Meter

box burning at a certain definite voltage. A voltmeter and rheostat permit the operator to adjust the lamp voltage to that at which the instrument was originally calibrated. The energy is supplied from small dry cells.

This instrument is proving very serviceable for "checking up" installations to insure, for example, that the illumination is ample when the projection equipment is in first-class shape and to see that it is not allowed to fall below a desirable value due to improper care and attention being given to the system. This instrument is of special value in securing data which can be applied in the designing of future installations.

The three units which have been discussed at length, the candle, the lumen and the foot-candle, will find wider and wider usage in the motion picture industry as their meanings become better understood. A discussion of light sources, for example, involves a discussion of intrinsic brilliancy (which means candle-power per square inch of luminous area) for upon the intrinsic brilliancy of a source depends in large measure its effectiveness in light projection. It involves a dis-

cussion of candle-power distribution of light, for upon this depends in large measure the design of the optical system. It involves a discussion of lumens output per unit of power input, for the source we use must be acceptable from the standpoint of light produced for energy consumed.

A discussion of the efficiency of optical systems involves the use of the unit of light flux, the lumen.

A discussion of screen illumination involves the use of the term lumen for expressing the total light flux reaching a screen, and the term foot-candle for discussing the distribution of the light flux over the area of the screen. The brightness of the screen involves, also, the term candle-power.

A discussion of theater lighting involves the terms candle-power, foot-candle, and lumen. The candle-power per unit of source area must be low in order that glare will be avoided, the foot-candle intensity must be sufficiently high to permit obstacles to be avoided, and the lumen output of the lamps must be sufficient to provide the proper foot-candle intensity.

As I have pointed out, the definitions are simple once their meaning and purpose are thoroughly understood. The following definitions have been accepted by many technical societies throughout the country.

Candle-Power—(C.P.)

The candle-power is the unit in which the luminous intensity of a light source is measured. Measurement of candle-power is not made directly, but is obtained by comparison with that produced by a standard under certain specified conditions.

The present unit of candle-power is referred to as the "International Candle," and is a unit 1.6 per cent smaller than the old "British" or old American candle, which was in use in the United States prior to 1909. The following table gives the relation between the units in use at the present time

1 International Candle=1 American Candle.
1 International Candle=1 French Candle, called "Bougie Decimale."
1 International Candle=1 English Candle, called "Pentane Candle."

If the intensity be measured in all directions in a plane perpendicular to the axis and passing through the center of the filament, the average of the values obtained would be called the mean horizontal candle-power. The axis of an incandescent lamp is assumed to be a line connecting the center of the base and the tip of the bulb.

The average of the candle-power intensities in all possible directions from the source is known as the mean spherical candle-power. Rating in terms of mean spherical candle-power is of supreme importance in comparing lamps having differently shaped filament. The mean spherical candle-power bears a definite relation to the total flux of light, and is, therefore, sometimes used as a measure of that quantity. The mean horizontal candle-power can not satisfactorily be used to indicate the light output of other than vacuum incandescent lamps and lamps without concentrated filaments; because of this limitation it is being superseded by ratings dependent directly upon the total light emitted. (See definition of "Lumen.")

Foot-Candle.

The intensity to which a surface is illuminated is measured in foot-candles. The intensity of illumination can be measured by a photometer or it can be calculated when the candle-power, direction and distance of the light source or sources is known. The illumination produced by a source of 1 c.p. on a perpendicular plane 1 foot away has an intensity of 1 foot-candle. When one lumen of flux uniformly covers 1 square foot of surface, the surface is illuminated to an intensity of 1 foot-candle.

$$\text{Foot-candles} = \frac{\text{CPX-Sine } \Phi}{D^2}$$

The c.p. is that of the source in the direction of the surface considered the angle is the angle between the light-ray (when the surface is perpendicular to the ray of light, the angle Φ is 90 degrees and sine I is 1.00). *D* is the distance in feet from the source to the surface.

This relation holds exactly only when the source dimensions are small compared with the distance of measurement.

Lumen.

The lumen is the unit of light flux. The flux required to light a given surface is proportional to the illumination and to the area of the surface. One lumen will light a surface of 1 square foot to an average intensity of 1 foot-candle. The number of lumens required to light a surface to any given illumination is equal to the product obtained by multiplying the area of the surface in square feet by the average foot-candles which it is desired to produce. Since a foot-candle of illumination is produced by a source of 1 c.p. shining on a surface one foot distant, if a source giving 1 c.p. in every direction is at the center of a hollow sphere of 1 foot radius every point on the interior surface of the sphere will be illuminated directly from the source to an illumination of 1 foot-candle. As the interior surface of the sphere of 1 foot radius has an area of 12.57 square feet and as the 1 c.p. source directly illuminates this area of 12.57 square feet to 1 foot-candle, the source must produce 12.57 lumens. Consequently a source of an intensity of 1 c.p. in every direction, which is 1 spherical candle-power, has an output of 12.57 lumens.

In view of their usefulness in the study of light projection, I suggest that these definitions be incorporated in the Standards of this Society and that this Society make an earnest effort to popularize them in the motion picture industry.

ADVANTAGES IN THE USE OF THE NEW STANDARD, NARROW WIDTH, SLOW-BURNING FILM FOR PORTABLE PROJECTORS

By W. B. Cook

At the last meeting in April at Rochester, your Society adopted a new size of narrow width, slow-burning film as the standard for all portable projectors. As the firm with which the writer is connected has had nearly five years of successful experience with a similar product, the Chairman of your Papers Committee has requested me to prepare and submit to you some actual facts of the advantages pertaining thereto.

Safety First

We owe a profound debt of gratitude, which will be better appreciated in later years, for the high and noble motives which actuated the sponsors of the new standard and also those members of your Society who co-operated so earnestly in the adoption of a standard which is designed to remove the portable projector industry from a severe and menacing cloud of public mistrust and legislative restriction.

The clearly recognized hazards of the use and even the storage of celluloid film have been not only pointed out by the Underwriters' Laboratories, but have been by them so insistently urged that not only the States, but practically all important municipalities have been compelled to surround the use and storage of celluloid films, within their jurisdiction, with such wise and protective restrictions as would tend to reduce to a minimum the hazards to which the members of the Commonwealth are constantly subjected in attending public or private cinematograph exhibitions.

In the last few years the growth and expanding fields of usefulness of the motion picture have surpassed the wildest imagination of its earlier advocates.

It has long been obvious that a medium of such wonderful educational value would inevitably be recognized as an essential for public instruction as well as entertainment. Progressive schools, churches and institutions have been quick to realize that in the motion picture lies one of the best aids to their usefulness.

It very soon became evident that the principal drawbacks to the general adoption of the motion picture in school, church and institutional work were the expense of the standard theatrical projectors, the specialized skill and knowledge required in their operation, and the deplorable lack of film subjects suitable for institutional use.

The first and second objections were sought to be overcome by the manufacture of cheaper and simpler forms of portable projectors, which could be easily carried from one room to another instead of being limited to a single auditorium, and whose simplicity of construction and operation would enable them to be operated by persons of very moderate mechanical skill.

But our very efficient guardians of life and property—the Insurance authorities—promptly pointed out that the principal hazard attendant upon such exhibitions lay, not in any hazard or use in the projector itself, but in the use and storage of the celluloid film used as a medium therein. The very advantages claimed in the use of the portable projector, namely, use without a booth and by people of limited mechanical skill, tremendously increased the film hazard beyond that attending its use in the standard machines enclosed in fireproof booths and under the operation of skillful attendants.

The obvious solution of the problem of hazard lay in the adoption of approved, slow-burning film, but the Underwriters' Laboratories again pointed out that unless the portable projector should be so constructed that it would be impossible to use ordinary celluloid film therein, it was a foregone conclusion that in the absence of any considerable quantity of available slow-burning film, the owners of such projectors would be sure to attempt the use of celluloid films therein (if such use should be possible) and the potential hazard would still remain exactly as before.

To cover the situation properly, the Underwriters' Laboratories suggested, and the National Association of Fire Prevention adopted the specific qualification:

"Approved miniature projectors must be so constructed that they cannot be used with films employed on the full sized commercial moving picture machine." (National Electric Code—Rule 38, Section V, Paragraph 6).

Various attempts have been made to comply with this requirement, such attempts being principally confined to the use of some form of odd perforation for standard width, slow-burning film, to fit a sprocket so constructed that it would mutilate ordinary celluloid film of standard perforation.

None of these attempts have met with any practical success and all of them are open to the serious, if not insurmountable objection that in the hands of any ordinarily intelligent but unscrupulous owner the mutilating sprocket could be very easily exchanged or altered so that it will run standard celluloid film.

Only Satisfactory Solution Is Adoption of a New Standard With Different Width and Perforation

Anything less than this is obviously not deserving and therefore cannot hope for permanent success.

It is only through the fact that the buyers are ignorant of the Underwriters' code and the criminal risk involved that they now purchase and use small portable projectors employing inflammable film. This intolerable condition has greatly retarded the natural expansion of the portable projector industry and the sooner we unite in removing it, the quicker will we enjoy the benefits of a healthy growth and expansion.

One manufacturer as long as seven or eight years ago took the lead boldly by adopting both an odd size and an odd perforation for use exclusively with slow-burning film, with the idea of insuring a thoroughly safe and approved apparatus.

This odd-sized machine and its film were, of course, regarded as an outlaw and suffered from the combined attacks of all other manufacturers of portable projectors designed to use the ordinary celluloid film.

In spite of the fact that the early users of the odd-sized machine were limited to the use of a very restricted repertoire of available subjects; in spite even of the fact that the earlier models of the machine had rather narrow limitations as to size and brilliance of picture, it has achieved some measure of success, as evidenced by the simple fact that more than ten thousand of them have been sold and are used all over the world, and more than 25,000,000 feet of printed positive on slow-burning stock has been made therefor.

The only possible explanation of this success lies in the fact that it was something that the public wanted. But why did they want it? At every stage of its career, this odd-sized machine has been exposed to the keenest individual and collective competition of all makers of portable projectors using standard celluloid film.

The answer requires but one word—*safety*.

If *safety* were the single and only advantage to be derived from this adoption of the new width and perforation, it would still be more than amply justified. But there are also other good and important advantages inherent therein. As a matter of fact, the adoption of the new standard is not merely a matter of business policy, but as pointed out above, it is an imperative necessity for the self-preservation and insured permanency of the portable projector industry. Anything short of a real approved projector is regarded as dangerous by the insurance, State and Municipal authorities and the user thereof with celluloid films is regarded as a menace to public safety.

Having decided that the industry absolutely required a new standard width and perforation, your Society naturally and wisely adopted one that makes immediately available some 25,000,000 feet of existing positive stock and also the facilities of several established plants for the further production of additional films, as they may be required.

Economy In the Use of the New Standard

In these days of increasing cost of materials, the item of economy is certainly one to be seriously considered.

The Eastman Company have been furnishing the new standard narrow-width at 80% of the cost per foot for ordinary width. Furthermore, the new standard narrow-width film will contain twenty pictures per foot instead of the sixteen of the present celluloid film. These two factors result in a combined economy or saving of 36% in the cost of stock for any given production. There is also, of course, a very considerable saving in the use of chemicals for developing, and also in the general handling and transportation of the narrow-width film, of which 800 feet in length is equivalent to the ordinary 1,000 foot celluloid reel.

Durability

Film experts seem to fairly well agree that the present deterioration in use of ordinary film is greater than it would be if the perforations were less numerous. In others words, that standard film is weakened

and its life is shortened by having so many as four perforations to each picture. The new standard with three perforations to each picture length would seem to be a logical improvement.

In conclusion and in simple justice to the firm which I represent, some pertinent facts should be made public.

Since the adoption of the new standard at your last meeting, some adverse criticisms have been launched by parties who pretend to see in the new standard a menace to their own self interests.

To an unprejudiced judge, it would seem that the only firm really entitled to complain of the adoption of the new standard would be the one that I represent, in that such adoption virtually wipes out and destroys in one instant a practical monopoly in a certain field, which had existed for a number of years. Your action in adopting the new standard was totally unexpected to us, and in fact it was nearly two months after its adoption before we ascertained definitely that it corresponded sufficiently to our product to take away the exclusive use of our most valuable feature.

Notwithstanding this blow to our own interests, and realizing broadly that the welfare of the industry as a whole infinitely exceeded that of any individual manufacturer, we at once communicated with the officers of your society and later with several of the prominent manufacturers of portable projectors, expressing our willingness to lend our co-operation in every way possible to those interested in the adoption of the new standard.

We herewith publicly offer to and through your Society of Motion Picture Engineers, all the facilities of our organization for the use of any other manufacturer of portable projectors.

Our Technical Department will furnish any dimensions or data as to the sizes of sprockets, film gates, aperture masks, etc., which our own rather extensive experience has enabled us to collect. Our Manufacturing Department will furnish to any other manufacturer any parts which may be of assistance to him in the more speedy adoption of the new standard than would be otherwise possible if each manufacturer were necessarily compelled to make such parts for himself.

We will perforate Eastman narrow-width, slow-burning stock with the new standard perforation for any film manufacturer that desires it.

Finally, our Laboratory and those of our Agencies will make reproductions from standard negatives or positives to the new narrow standard for any users of the new standard portable projectors.

Discussion

After Mr. Cook's paper, Mr. De Vry contributed some discussion to show that the use of non-flam stock for large standard film would make for safer general conditions, and would be more practical than to have two standards—one flam film and one non-flam film standard. He used as the basis of his remarks, the experience in France, and said that if interest enough were shown in the United States, it would be possible to obtain non-flam stock in quantities, as good as the present flam film.

Mr. Cook stated that the law passed in France, referred to by Mr.

De Vry, never became operative because it was postponed every date at which it was to become operative, by representations of the industry that it would be confiscatory to. The theatres in France today are running the same films as used here, because they find it impractical to sacrifice interests, which in France are infinitesimal in comparison to the vast interests in this country.